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Ensuring Drinking Water Quality in Ontario: A Framework

Submission to the Walkerton Inquiry
By the Association of Local Public Health Agencies (alPHa)

May 7, 2001

Executive Summary

In Ontario, 23 percent of water use is from groundwater (Ontario Federation of Agriculture, 1998). This percentage is significantly higher in rural Ontario, where most water delivery systems start with the construction of wells that provide the means of access to a dependable subterranean water supply. Groundwater sources have been traditionally viewed as presenting little risk to health in their natural state. As a result, there was less emphasis on the stringent types of treatment, testing and monitoring strategies that are designed to minimize risks to health characteristic of surface water sources.

The May, 2000 outbreak of *E.Coli* O157: H:7 in Walkerton, Ontario is the latest and most significant indication that the historical confidence in the quality of groundwater is no longer a given. As pressures on watersheds grow with increased and intensified human activity within them, more consideration must be given to their potential negative impacts on water sources and to strategies designed to minimize them.

The purpose of this paper is to examine the delivery of drinking water from ground water sources from the perspective of protecting human health by minimizing the risk of water-borne disease. The main focus will be on microbiological hazards, which are the most common causes of acute water-borne disease, are ubiquitous, and are relatively easy to prevent. As the majority of water-borne disease occurs in rural areas, the discussion will be limited to smaller water delivery systems, which are regulated, but not necessarily as sophisticated as utilities serving large urban populations. In examining the flow of water from “source to tap”, a systematic approach that includes risk assessment, hazard identification and control, monitoring, contingency plans and verification will be employed to suggest a framework for a more detailed quality assurance system for drinking water.

The approach is based on the Hazard Analysis Critical Control Point (HACCP) protocol, which is a health hazard mitigation strategy that has bee used for years in public health to evaluate food safety. It involves the examination of all steps in the process to identify hazards and specific methods to reduce or eliminate them. Risk identification and controls, monitoring strategies, contingency plans and verification will be addressed in each of three steps in the water delivery system – source, distribution system and end user.

SOURCE

The natural hydrological cycle will, in the absence of other factors, generally provide a plentiful source of clean water. As surface water percolates through the soil, contaminants are removed or rendered innocuous before the water reaches the groundwater source. Human activity within watersheds however does have significant impacts on this cycle, both directly and through its byproducts, including chemical, biological and physical contaminants. If enough of these are carried by water leaching through the soil, they may reach the groundwater source. Once there, these contaminants undergo little or no transformation. Control of pollution sources on the surface is thus essential to the protection if the water resource beneath it.

The primary reason behind protecting the water source is to protect human health – by ensuring that drinking water is available and free of disease causing agents, whether they are physical, chemical or biological. Community water systems outbreaks generally occur in small water systems serving rural areas, and are primarily the result of contamination from sewage, which is the reservoir for many of the infectious disease agents that cause them. If the source of these infectious agents is shared (e.g. water supply), widespread outbreaks may occur. The proper provision and management of drinking water supplies depends on looking after water at all points between the source and the end-user. Source protection is the first line of defence in the provision of safe and acceptable drinking water.

Risk Assessment and Hazard Identification

Watershed management and monitoring

The first step in providing potable water is the location of sufficient and useable water-bearing formations. Effective watershed management and monitoring must begin with a hydrogeological assessment to characterize the quality and quantity of the source as well as its sensitivity to human impacts. What must follow is an analysis of these impacts, which means itemizing and evaluating past, existing and intended land uses within the watershed. The controllable sources of contamination result primarily from activities that occur in close proximity to the sources of water. Protecting the source of water thus requires the elimination, reduction or strict regulation of these processes. By examining the interaction among the natural processes that maintain the aquifer and the human activities that influence them, strategies to maximize sustainability and safety can be identified.

Land Use

Strategies for the protection of the groundwater source will primarily be based on controlling the potential for entry of pollutants from land uses in the watershed. This requires a full analysis of what types of byproducts are associated with these uses, and what their potential impacts are. Once determined, appropriate limitations can be placed on them

In the first instance, careful planning for development must include proper consideration of waste management, sewage treatment, location of industries, and maintaining the natural recharge of the water source. Integrating natural cleansing properties of soil in planning and development is essential to ensuring the continued viability of the aquifer.

Agriculture has enormous impacts on the natural environment, and their proper management is crucial. Many farm practices are potential sources of contaminants, the most significant of which is the handling of manure. Manure is rich in microorganisms, most of which are harmless or even beneficial, but several of which can cause serious illness in the right circumstances. Its storage, handling and application as fertilizer must therefore be carefully managed to prevent it from contaminating water.

The same potential impacts on groundwater exist in human sewage and other wastes. In rural areas, septic systems are the most common method of sewage treatment. These are relatively simple technologies whose proper function depends on the natural cleansing properties of the soil in which they are laid. Solids are removed from the effluent, which is discharged into a leaching bed to be filtered through the soil. The proper construction, maintenance and location of these systems is essential to ensure that disease-causing organisms (pathogens) and other contaminants are broken down or filtered out before the effluent reaches the aquifer.

Wells will also be addressed in terms of source protection.. As with septic systems, their proper construction, maintenance and location are essential to the protection of the water. Defective wells are direct access points for contamination to the aquifer.

Control of Health Hazards

Once the source water has been assessed, past and present land uses have been itemized, the decision to take water has been made and potential hazards have been identified, strategies to protect the source water must be implemented. The protection of the groundwater source is the first of a series of barriers that ensure clean drinking water. Provincial and federal governments share responsibilities for agriculture, health and ensuring the provision of a safe and sufficient supply of water for all Canadians. It is thus incumbent upon them to enact policies that support these responsibilities, including the protection of watershed areas and regulation of development, well and septic system construction and land uses.

Monitoring Criteria

Monitoring the source water itself should complement the observation of activities in the area that are sources of these contaminants. Routine monitoring of water quality in domestic and municipal wells drilled into a given aquifer is the most effective way of ensuring that the source water meets prescribed health-related parameters. Assessment of the source and contaminants produced in the area will also be needed to ensure that the type of treatment at the water plant is appropriate to disinfect the water. Ontario’s new Drinking Water Protection Regulation prescribes minimum treatment requirements, but also provides for exemptions.

Contingency Plans

Regardless of the measures taken to prevent the contamination of groundwater, the possibility always remains that it may occur. This possibility requires contingency planning. Procedures must be in place to deal with contamination incidents quickly and effectively, to protect human health and to minimize damage to the aquifer as much as possible. The MOE, through its Spills Action Centre (SAC) initiates and coordinates responses to incidents of environmental contamination, including those that threaten water.

Verification System

Regulating land and water use are integral parts of preventing groundwater contamination. Groundwater recharge zones must be protected not only by prohibitive or restrictive legislation, but also by the verification system enabled by the legislation to ensure compliance. The various licensing requirements, approvals processes and record keeping functions required by the Environmental Protection, Building Code and Water Resources Acts form the basis of a surveillance system for the types of activities requiring regulatory attention within a given watershed. Routine inspections and evaluations of these activities (e.g. farm practices, industrial activities, wells and septic systems) would give provincial authorities the opportunity to identify problems, give the persons responsible the opportunity to correct them, with the understanding that failure to do so will result in penalties.

The appropriate combination of permits, licenses, record-keeping and routine inspections constitutes an effective verification process. Inspectors designated by legislation governing various land uses, farm practices, wells, septic systems and general environmental protection together verify that the protective systems that ought to be in place in fact are. The verification functions enabled by statutes, regulations and by-laws should be mandatory and of appropriate frequency. This function, like monitoring, serves to identify situations that might evolve into real threats to source water before they have the opportunity to do so.

DISTRIBUTION SYSTEM

The provision of safe, high quality drinking water will depend on a well-constructed, well-monitored and well-maintained distribution system. The distribution system refers to all of the infrastructure and processes from the extraction of water from its source to its delivery to the consumer’s tap. It includes the treatment; testing and monitoring of water quality throughout the system, and the maintenance, and monitoring of the system itself from one end to the other.

Risk Assesment and Hazard Identification

Detailed plans of the entire system must be examined by all appropriate agencies. Considerations should be given to what types of materials are permitted, and written policies and procedures for monitoring, maintenance and contingency plans should exist. In order to minimize potential health hazards at this point, an examination of intended design, use, materials and capacity should be carried out. Approval would be given once the issuing body is satisfied that the design, materials, maintenance, policies, procedures and proposed contingency plan are adequate for the provision of safe and sufficient potable water to those served by the system.

The quality and quantity of the source water, an inventory of all land uses and their locations, wells and wastewater systems will also be invaluable information for an assessment of the distribution system. Testing and monitoring requirements in particular should be based on local conditions. The hazards that threaten source water are, under the right circumstances, the same ones that might threaten it in the distribution system. Being aware of existing risks allows for their management in the planning stages.

Control of Health Hazards

Once drawn from the source, the delivery of safe water to the customer depends on the monitoring for biological and physical indicators on a frequent, routine and long-term basis to detect the presence of contaminants, and treatment strategies to exclude them from all parts of the system. Information regarding land uses in the vicinity of the water source will determine the types of contaminants to be included in the monitoring protocol and the types of treatment necessary at the waterworks.

Ongoing monitoring of changes in local land use activities will also be an invaluable tool for ensuring that emerging hazards are always accounted for and safeguards altered accordingly. Four categories of contaminants are included in the Ontario Drinking Water Standards – physical, chemical, radiological and microbiological. The sources, health effects, permissible concentrations, monitoring and control measures differ for each.

Contaminants

Chemical contaminants may be found in water naturally, or as a result of discharges from various land uses, and can cause adverse health effects in high enough concentrations. Setting limits for those that could be found in drinking water and requiring their monitoring are designed to minimize exposures that may cause such effects. Physical contaminants are generally innocuous on their own, but high levels of turbidity may interfere with treatment processes, and are precursors to the formation of trihalomethanes, which are chlorine compounds that are being studied as possible carcinogens. Radiological parameters are also established, based on the idea that exposure to them at any level carries some degree of risk. These are not addressed here in significant detail, but specific parameters for each are set out in the Ontario Drinking Water Standards, which must be followed as part of a complete approach to ensuring water quality.

Bacterial pathogens are the most significant cause of water-borne disease outbreaks and thus the main concern from the perspective of public health. A significant number of these are residents of the intestinal tracts of warm-blooded animals, and are released into the environment with their waste. Septic systems, cesspools, domestic feedlots, manure storage and application are thus important sources of these. Pathogens of note include (but are not nearly limited to) bacteria such as *Salmonella, Campylobacter, Shigella, E.Coli* and *Clostridium* protozoa such as *Cryptosporidium* and *Giarda* and viruses such as Hepatitis A. These all have different effects, but their mode of transmission (fecal-oral) is the same. Broad-based strategies to prevent contamination of groundwater in general and their entry into the distribution system specifically will therefore prevent the entry of these organisms into their infectious pathways.

Treatment methods

The characteristics of raw water should determine the method of treatment. Several treatment technologies exist, and the type of treatment chosen should be site specific and should depend on results of initial chemical, physical and microscopic examinations (Salvato: 257). Disinfectant dosages need to be determined by the extent of pollution of source water, type of microorganisms and other contaminants likely to be present, pH of the water and other treatment methods employed. The new Drinking Water Protection Regulation (DWPR) requires a minimum treatment consisting of chlorination. Surface water sources must also be filtered.

The effectiveness of proper disinfection including inactivation of viruses, other conditions being the same, is largely dependent on the freedom from suspended material and organic matter in the water being treated (Salvato: 257). Filtration is thus a key component in a treatment system, where particles are removed from water when it passes through a medium of sand, anthracite or another suitable material. Microfiltration and ultrafiltration are types of filtration differing in pore size. They are both promising treatment practices, which are proven to remove protozoan cysts and oocysts (Braghetta et. al: 8), which are likely to resist the disinfectant properties of chlorine. Microfiltration (minimum pore size 0.2μm) has been demonstrated to achieve absolute removal of protozoan species (ibid.). Ultrafiltration achieves absolute removal of protozoa and significant removal of viruses (ibid.). Given the effectiveness of filters it is possible to remove virtually all sediments and larger waterborne pathogens such as giardia and cryptosporidium (Christensen and Parfitt: 21).

Coagulation, Flocculation and Sedimentation are also useful methods of removing particulates. During coagulation chemicals are added to the water to destabilize suspended or colloidal solids. Under normal conditions, colloidal material will not settle out, because particles have a negative charge on their surface and repel other particles (Driscoll: 799). Particles therefore remain suspended in solution. By adding coagulants such as aluminum, iron salts and catonic polymers, the negative charge is neutralized and particles will coagulate into larger masses that then settle out (ibid. 800). Optimally under this process, 80 percent of turbidity and bacteria is removed.

Ultraviolet radiation is another physical method receiving increased consideration. UV radiation can effectively neutralize bacteria, viruses and cysts when properly applied. Recent research has demonstrated that it may also be effective against the more stubborn protozoa such as *Cryptosporidium* and *Giardia* (MOE, 2001: 48). Development of this technology continues, but for now, there are two major drawbacks in its use as a disinfectant – there is no disinfectant residual beyond the point of treatment and any turbidity in the water will interfere significantly with its effectiveness. The ODWS position on this is that “chlorine or other disinfectant must be added after disinfection with UV in order to provide a residual which can be maintained throughout the distribution system” (ibid.).

Chlorine is the chemical disinfectant of choice in the majority of water systems. In most cases chlorination is the least costly, easiest to apply and often the best method to disinfect public water supplies and control bacterial growth in the distribution system. Small amounts of chlorine remaining in the distribution system will serve as a disinfectant from the treatment plant to the tap. Chlorine reacts with (oxidizes) substances present in water such as organic material and inorganic materials, and kills most pathogens on contact with relatively low doses.

In the second edition of its “Guidelines for Drinking Water” 1993, the World Health Organization stated: “Disinfection is unquestionably the most important step in the treatment of water for public supply. The destruction of microbiological pathogens is essential and almost invariably involves the use of reactive chemical agents such as chlorine, which are not only powerful biocides but also capable of reacting with other water constituents to form new compounds with potentially long-term effects" (World Health Organization, 1993).

The Ontario Drinking Water Protection Regulation states that no water will be allowed to enter a distribution system or plumbing unless it has been chlorinated or equivalent (except in cases where a variance is sought). For now, the requirement to chlorinate in all cases seems to be the wisest one. The wording of the regulation allows for exemptions and alternatives, but a stringent set of circumstances must be applied in granting such approvals. The standard for granting variances must in all cases be the effective prevention of water borne disease.

Ozone is an unstable form of oxygen, which can be generated from air or oxygen and bubbled through the water acting as a disinfectant. It is also a strong oxidant and powerful germicidal agent, which is effective in killing bacteria and viruses including giardia and cryptosporidium (Christensen and Parfitt, 2001: 22). Ozone requires a short contact time with water and is effective over a wide pH and temperature range in contrast with chlorine (Salvato, 1982: 294). Ozone is however not a practical disinfectant in water systems because, like UV light, it is not an active disinfectant residual in the distribution system .

Other Operating Criteria

Successful and responsible operation of a waterworks plant involves many aspects. In addition to treatment criteria there are other operating guidelines which are necessary to ensure that existing procedures are followed. The employees performing plant functions need to be capable individuals with knowledge of relevant policies and procedures and the reasons for them for waterworks to operate correctly.

Monitoring Criteria

A complete monitoring protocol will include types, locations and frequency of samples to be taken, based on the source of the water, treatment methods and population served. It is essential that the monitoring process be properly carried out to satisfy its purpose, which is to detect substances that may cause adverse health effects in the absence of any changes in taste, odour or appearance of the water. For this reason, detailed sampling and analysis requirements have been set out in the DWPR. Prior to this, testing was carried out under the non-binding protocols of the Ontario Drinking Water Objectives. To ensure accurate results and their proper reporting, laboratories performing these analyses must now be accredited (O. Regulation 459/00, s. 7(3)).

Testing must address immediate and long-term health risks as well aesthetic parameters. Because there are so many substances listed in the standards, each requiring specific, often costly lab tests, frequent testing for all of them by small community water works would neither be practical nor affordable. The protocol should thus focus on contaminants identified during land use assessments.

Sources of Standards

The Ontario Drinking Water Objectives for many years set the maximum limits for over 80 contaminants that have known or suspected adverse health effects in sufficient concentration. They are divided into chemical, physical, radiological and microbiological categories. Limits were set for each as Maximum Acceptable Concentrations (MAC), the surpassing of which was intended to trigger reporting and corrective actions. Where there was not sufficient toxicological data to establish a MAC with reasonable certainty or not practical to establish a MAC at the desirable level, an Interim Maximum Acceptable Concentration (IMAC) would be established. These were also triggers for reporting and corrective action. All of this is still the case, but the Objectives, since being adopted by reference in new legislation, are now Standards, which means that corrective actions and reporting are now mandatory. Requirements over and above these may be set out as conditions of approvals, orders or directions issued by the MOE on a case-by-case basis.

Microbiological Standards

A number of diseases can be transmitted by drinking water by a number of infectious agents (or pathogens). Testing for each of these requires a specific detection procedure, which can be costly and time consuming. Additionally, some of these infectious agents cause disease at concentrations low enough to make such detection exceedingly difficult. As most of the pathogens of concern are residents of the gastro-intestinal tract of warm-blooded animals, a general test for indicator organisms that also reside there is used.

Coliforms are a group of microbes that serve as useful indicators of fecal contamination as they are plentiful, easy to detect by a simple and inexpensive test, and hardier outside of their hosts than the pathogens. Coliforms have thus become universal indicators of the contamination of water by sewage, and therefore the possible presence of pathogens. According to Ontario's new Drinking Water Protection Regulation, if E. coli, fecal coliforms or total coliforms are detected in any sample other than a raw water sample it is an indicator of adverse water quality. Once any of these is detected in sufficient numbers, reporting, resampling and treatment protocols are implemented.

Other Standards

The new DWPR in Ontario lists 84 new, revised or reaffirmed drinking water standards. It puts in effect binding sampling and analysis requirements for microbiological, chemical, radiological and physical parameters. The frequency depends on the source of the water, population served, and treatment methods employed.

In addition to the maximum limits set for hazardous substances, monitoring criteria must be established for the treatments meant to reduce them. To reduce the risk to human health from distribution system contamination, a minimum chlorine residual level must be present throughout the system. Monitoring this will require sampling points throughout the distribution network. Inadequate chlorine residual allows the potential for regrowth of pathogens in the distribution system and should be taken seriously. The new DWPR identifies residual levels below 0.5 mg/L as an indicator of adverse water quality, requiring immediate correction and consultation with the local MOH (O.Reg 459/00, Sch. 6).

Testing Requirements

The basic objective of drinking water monitoring is to ensure that drinking water is potable and aesthetically acceptable. A proper testing protocol will assess compliance with the ODWS and with any terms and conditions set out in Certificates of Approval. Consistent application and recording will allow the identification of trends and changes in water quality, providing early warnings of those that might be detrimental. Specific requirements for monitoring a wide range of standards are set out in the ODWS and are legally enforceable under the DWPR.

In order to ensure that monitoring serves its purpose, it must be properly carried out. The use of sterilized containers, locations representing the delivery system as a whole, proper storage during transport and time between sampling and analysis are all important considerations to ensure that test results accurately reflect the characteristics of the water at the time of sampling. Training of operators as well as environmental officers charged with such verification duties must be available. On August 8, 2000, the Minister of the Environment announced the intention to require all operators to undergo an additional 36 hours of ministry approved training over three years to ensure they have the most current knowledge, skills and experience needed to sample water quality. In addition, a new license will be created for water quality analysts. This license will be required to perform a range of tests for operational parameters (MOE, 2000). Finally, the mandatory accreditation of analytical laboratories under the DWPR should add extra confidence in results from analyses that require their services. In the long run, conscientious application and verification of the monitoring protocol (frequent and documented sampling of raw, treated and distributed water) will increase public confidence in its drinking water.

In addition to monitoring water quality parameters, there must be procedures in place to ensure that distribution system materials and equipment are in good repair at all times. Given the potential for contamination to spread quickly throughout a distribution network, thorough inspections of the hardware itself are essential. Installation, testing and repair schedules for piping, water storage facilities and pumps are all part of the effective oversight and management of the operation of the system and the delivery of safe water.

Verification System

As with the regulation of land activities discussed above, the regulation of water delivery systems enables a verification system based on routine inspections, investigations, enforcement and clear reporting strategies. In addition to these, a public disclosure framework is built in, which ensures that records of processes are available for public viewing. Together, these can be useful assurances that water works staff is carrying out their duties diligently, and that public confidence in the water supply is maintained.

END USER

The primary purpose of the assessments, safeguards and contingency plans referred to in the preceding sections is to ensure that the water that reaches its consumer is of acceptable quality and is safe to drink. The process that starts with source water and ends at the tap involves many protective measures, whose success depends on different types of expertise. The responsibilities for ensuring the protection and maintenance of drinking water thus lie with different agencies. The protection of the health of the end user however falls squarely within the purview of the public health system. This system thus constitutes the final barrier in the process.

This system comprises the local boards of health that are responsible for community health protection in each of Ontario's 37 health units. Their authority for this responsibility originates mainly in the Health Protection and Promotion Act and the Mandatory Health Programs and Services Guidelines (MHPSG). Among these is ensuring that community drinking water systems meet health-related standards as published in the ODWS, with a view to reducing the incidence of water-borne illness in the population.

From a public health perspective, the control of health hazards begins before they have the opportunity to cause adverse effects. This can be accomplished in different ways according to circumstance, but raising awareness is always essential. Requirement 5 of the Health Hazard Investigation program states that the Board of Health shall provide educational materials to raise public awareness of health hazards, including information on various public health issues related to drinking water

Boards of health must also investigate, identify and manage health hazards. Local health departments actively monitor water quality in some cases, but this duty generally originates from reports of adverse water quality results or of outbreaks of disease in the community Timely response to such reports (regardless of their origin) is required of the board of health by the Mandatory Health Programs and Services Guidelines. Under Health Hazard Investigation requirements, boards of health must provide 24-hour availability of staff, same day assessment and initiation of action within 24 hours of confirmation of a health hazard

Upon receipt of adverse water quality reports, board of health staff can quickly initiate appropriate action to reduce adverse health outcomes resulting from exposure to health hazards. Action on an adverse water quality report may take on different forms, as allowed by the broad provisions of Section 13 of the HPPA: The most common of these is the issuance of boil water advisories.

Included in this procedure are requirements for the provision of timely and essential information to the community and monitoring health hazard management strategies. The purpose of these requirements is to identify health hazards, take appropriate action in order to ensure community health protection and continued public health services delivery in the event of a health hazard (ibid.)

Boards of health are required to have a written protocol to deal with reports of adverse water quality. In some cases, it will suffice to monitor the corrective actions of the owner of the water works. In others, actions may include superchlorination or flushing orders in conjunction with immediate public notification to boil water or seek alternate sources. In either case (as with the range in between) the health department must act quickly, in conjunction with other responsible agencies, to enact measures to protect community health when sample results indicate potentially unsafe drinking water. The success of this corrective action will depend on a detailed and clear response protocol, that itemizes in detail the steps that are to be taken in what circumstances and by whom.

Because the failure of the safeguards that trigger the contingency plan may constitute a danger to public health, clear, quick and effective public communication procedures must be followed. How this is done will depend on the community, but the goal will always be that every individual is made aware of the problem and of any measures he or she should be taking to minimize risks to their health. Print and broadcast media, handbills, and door-to-door visits are all useful tools for the delivery of this type of information. Having determined the methods of communication, it is also important to define the content of the messages. Issuing a boil water advisory for example should define what it is, how to do it properly, why it is necessary and effective, and how to obtain further information.

The decision to issue boil water advisories or orders rests with the medical officer of health, and there should be criteria spelled out for when this decision should be made and how it is to be disseminated. While consistent province-wide standards for the former would be useful, the process of informing the public will differ among the health units.

CONCLUSION

In the of the process of extracting water from its source and delivering it to the public, a complex web of interconnected processes is illustrated. For all of the fragmentation of responsibility, division of labour and diversity of expertise involved, the unifying factor is the end goal – to ensure that the water coming out of the tap of the end user poses no threat to his or her health. Following the Walkerton tragedy, many analysts spoke of the recent complacency over the safety of drinking water. The fact is that with the implementation of and constant vigilance over appropriate controls, which are known and in many cases already in place, perhaps the end user should be permitted to take the safety of his or her water for granted. It is up to regulatory agencies, government ministries and technicians who are involved in the delivery of that water to give that permission by fulfilling their obligations and communicating effectively with each other.

1.0 INTRODUCTION/OVERVIEW

Canada has long enjoyed one of the safest and most plentiful water supplies in the world. It contains nine percent of the world's freshwater supply, 90 percent of which is stored as groundwater (Dumanski et. al., 1994). Between 25 and 30 percent of the population relies on groundwater, 70 percent of which live in rural areas (ibid.). In Ontario, 23 percent of water use is from groundwater (Ontario Federation of Agriculture, 1998). This percentage is significantly higher in rural Ontario, where most water delivery systems start with the construction of wells that provide the means of access to a dependable subterranean water supply.

Generally protected from direct contamination and existing in an environment that is not ideal for the growth of microorganisms that may cause illness, fresh water obtained from ground sources has traditionally been perceived as relatively safe in its natural state. As a result, there was less emphasis on the stringent types of treatment, testing and monitoring strategies that are designed to minimize risks to health characteristic of surface water sources.

It has become clear in the recent past that increasing pressure on this valuable resource by human development, concentration of populations and industry, and changes in public infrastructure are resulting in increased risk of water-borne disease outbreaks. In addition, emerging pathogens such as *Cryptosporidium* and *Cyclospora* are beginning to challenge the preventive measures that are already in place to decrease this risk. *Cryptosporidium*, a parasite resistant to chlorine treatment, was responsible for two high-profile outbreaks in Milwaukee and Collingwood in the last decade. *E.Coli 0157:H:7* is another emerging pathogen that was quickly becoming a household word due to large outbreaks of serious gastrointestinal illness associated with the consumption of undercooked ground beef. More recently, it was identified as the main infectious agent behind the May 2000 water-borne outbreak in Walkerton, Ontario, where seven died and nearly two thousand fell ill. This was an unfortunate and unprecedented confirmation that the security of groundwater could no longer be taken for granted.

The purpose of this paper is to examine the drinking-water delivery process from the perspective of protecting human health. Its focus will be on those systems that, under Ontario law, are classified as large water works, but use groundwater as a source and serve relatively small populations. While several different types of water-associated hazards will be addressed, the main discussion will be limited to protecting these populations from the adverse health effects associated with pathogenic bacteria, protozoa and viruses. These are ubiquitous in the natural environment, necessitating immediate and ongoing protective measures. By surveying the process as a whole (from source to consumer), potential health hazards as well as steps that should be taken to minimize or eliminate them will be identified. This quality assurance system will be loosely based on an adaptation of the Hazard Analysis Critical Control Point (HACCP) Protocol, which has long been used by public health authorities for the evaluation of food-handling practices.

A Quality Assurance Framework

The HACCP approach to health hazard prevention, elimination and control is a common-sense method of assessing risks to health in a product flow, and devising methods to minimize them. With proper evaluation and monitoring, effective contingency plans and a clear definition of responsibilities, it could be a valuable tool for the maintenance of the integrity and safety of the public water supply. In exchanging the HACCP focus on food for one on water, the protocol might read as follows:

Goal:
To improve the health of the population by reducing the incidence of water-borne illness

Sub-Goals:

- To evaluate water delivery systems while maintaining a high level of compliance with design criteria and basic sanitation maintenance.
- To improve safety of drinking water in the delivery system through more focused evaluation, education, consultation and regulatory enforcement strategies.
- To optimize the resources of public bodies with responsibility for water quality by prioritizing areas of highest risk
- To promote self-monitoring of water works by operators and staff well trained in quality assurance principles
- To monitor and evaluate the level of compliance with practices necessary to the provision of safe water.

In order to achieve these goals, a systematic approach must be employed, which consists of the following major steps:

- Risk assessment, including the identification of actual and potential health hazards at each step of the water-delivery process
- Identifying points in the process (Critical Control Points) where hazards can be minimized or eliminated and establishing operating criteria
- Developing monitoring criteria
- Establishing contingency plans for when operating or monitoring criteria are not met.
- Verification of the protocol – that it is being followed and that the criteria are appropriate.

The provision of a safe and adequate supply of potable water requires the implementation of strategies using this approach, including strategies for source protection, treatment, monitoring, distribution system maintenance and proper operation. Plans must also be in place to deal with any failures in the system, to ensure that contaminated water is not consumed. In other words, the identification, prevention, and correction of contamination problems must be exercised at logical points in the process, and responsibility for implementing these strategies will depend on which step in the process is being addressed. Ensuring water quality from source to consumer will thus require a collaborative effort among agencies with authority over the following major components:

Source
The supply of potable water to a community begins with the location of the best available source and must include planning for its protection and sustainability. In applying the HACCP-style approach when considering issues around watershed management, land use (e.g. agriculture, industry), wastewater collection and disposal, and well construction, potential risks to the source itself can be identified and controlled. Agricultural, environmental and building standards will all be important factors in ensuring that the viability of the source is sustained.

Distribution system
Once the source has been located and its attendant risks have been identified, the means of its delivery as drinking water must be properly planned and maintained. Population served, uses, treatment and monitoring requirements, operator training, engineering and maintenance of distribution infrastructure must all be carefully considered to ensure that there are measures in place throughout the system to prevent, identify and control contamination. It is here that the proposed quality assurance framework will be applied to greatest effect. Risk assessment, hazard identification and control, monitoring and operating criteria, contingency plans and a verification system are essential components of how most community water works conduct their business.

Point-of-use.
The purpose of a quality assurance system based on environmental and operational standards and best practices is to ensure that the consumer can reasonably assume that the water coming out of his or her tap is safe and of acceptable quality. Nevertheless, there are end-user considerations that will be addressed. Public education, notification of water quality problems and systems set up to receive reports of point-of-use water quality problems are all integral to ensuring that the approach fulfills the goal of ultimately protecting public health from water-borne hazards. The statutory authority under which boards of health do business, when integrated into the overall strategy, will be shown as a powerful tool for achieving this goal.

2.0 SOURCE

Ground Water

Groundwater is recharged by precipitation, which percolates through the soil, travelling downward by gravity through soil layers into porous rock and gravel. The groundwater zone is basically a natural reservoir or system of reservoirs in rocks whose capacity is the total volume of pores or openings that are filled with water (Driscoll, 1995: 61). These pores or openings within a geologic formation are referred to as an aquifer, which is defined as a saturated bed, formation or group of formations, which yields water in a sufficient quantity to be economically useful (ibid: 62). The area of land that provides water to the aquifer called the recharge area, the dimensions of which will depend on unseen aquifer boundaries. Knowing where these boundaries are will indicate the size and shape of the recharge area, allowing for proper evaluation and mitigation of risks from intended land use practices or geological weaknesses within it.

Recharge can be defined as the rate at which an aquifer replenishes itself. The recharge rate will depend on the location, amount and frequency of rainfall. This cycling of water will, in the absence of other factors, generally provide a plentiful source of clean water. Unfortunately, other factors can and do come into play, most of which result from land use activities associated with human settlements.

During the slow percolation of water through the soil, several processes may occur to cleanse the recharge water of impurities dissolved at ground level before it reaches the aquifer. These include adsorption to soil particles, digestion by micro-organisms, breakdown into harmless compounds or simple decay. It is the overburdening or circumvention of these natural processes in a recharge area that poses the greatest threat to the water source. The renewal and dependability of the water source in a given recharge area can be severely compromised or even lost if excessive contamination is allowed, recharge areas are eliminated or unprotected, or groundwater is withdrawn excessively (ibid: 838). This is why careful consideration must be given to proper planning of land use in the recharge area, in order to reduce the potential for pollutants to reach the water source, and to ensure its sustainability.

The percolation of water downwards through the soil acts as a cleansing process when operating optimally. The filtering and cleansing capacity of the recharge area can be exceeded if there is a sufficient concentration of pollutants on the surface. If enough are carried by water leaching through the soil, contaminants may reach the aquifer. Once the water reaches the aquifer there is little change to water because there is almost no chemical activity - it is cool, dark, and lacking oxygen and microorganisms (Stewart, 1990: 41). This means that if contaminants do reach the aquifer there is little chance of additional cleansing taking place. Control of pollution sources on the surface is thus essential to the protection if the water resource beneath it.

Measures must also be taken to ensure that the characteristics of the recharge area itself are not drastically changed by the activities for which it becomes necessary to put the water source to use. The details of this are beyond the scope of this paper, but consideration should be given to the potential for development to alter the recharge process through increased erosion, changing runoff patterns and excavations (including wells) that reduce natural protection of the groundwater.

Consideration must also be given to natural geological risk factors. Fractures or large pores in the Earth’s surface provide a quick and direct route to the aquifer, bypassing the natural cleansing processes referred to above. The rate at which water drains through the soil is also a factor, dependent on the type of soil present. For example water will move slowly through a non-porous soil like clay but relatively quicker through porous media such as sandy soils (Stewart: 42). If the percolation time is too slow, water may pool, absorb higher concentrations of contaminants and move laterally across the surface to a more conducive drainage site. On the other hand, if percolation time is too fast, contaminants may reach the aquifer not having had enough time to undergo natural purification.

The first step in protecting groundwater is thus a basic understanding of its natural processes, knowledge of a given aquifer's inherent sensitivities, and a detailed understanding of how each can be altered by the activities that necessitate its use. Reversing the damage caused by contamination might be cost-prohibitive if not impossible. It is thus vital that groundwater resources be protected from contamination through proper planning..

Contamination and disease.
The primary reason behind protecting the water source is to protect human health – by ensuring that drinking water is available and free of disease causing agents, whether they are physical, chemical or biological.   Common concerns for groundwater contamination in rural areas in regards to human health include contamination with pathogenic microorganisms, nitrate and toxic organic compounds. This paper will primarily address the acute health effects of bacterial, viral and protozoan pathogens rather than the chronic risks associated with low levels of toxins (e.g. trihalomethanes) or those associated with extraordinary and sudden gross contamination (e.g. a subterranean chemical spill). While the latter should not be ignored, the adverse health effects of the former tend to be known, immediate and widespread. Because we know the sources and modes of transmission of these infectious agents, we also know of effective ways to prevent or control them.

Community water systems outbreaks generally occur in small water systems serving rural areas, and are primarily the result of contamination from sewage (Salvato, 1982:42), which is the reservoir for many of the infectious disease agents that cause them. Examples of these include bacteria (*E. coli, Campylobacter, Salmonella*), viruses (Hepatitis A) and pathogenic protozoa (*Giardia intestinalis*). Adverse health effects vary according to type of agent, dose, and the affected person's immune response - in the right circumstances, the health effects of any of these agents can be extremely serious. If the source of these infectious agents is shared (e.g. water supply), widespread outbreaks may occur. These outbreaks are generally a result of disregard for or a failure of known fundamental sanitary principles and are thus largely preventable (Salvato, 1982:23).

The key question that must be answered during risk assessment and strategic planning is, what needs to be done to ensure that contaminants, by natural processes or by intervention, are excluded from the aquifer.

2.1 Risk Assessment, Hazard Identification and Control

The proper provision and management of drinking water supplies depends on looking after water at all points between the source and the end-user. While protecting source water requires more broad-based and coordinated effort from more stakeholders, it must not be abandoned in favour of disinfecting and decontaminating. Source protection is the first line of defence in the provision of safe and acceptable drinking water.

The first step in providing potable water is the location of sufficient and useable water-bearing formations. Information about the characteristics of the local watershed helps to determine the quality of the source. Once an acceptable and reliable one has been found, steps must be taken to ensure that it continues to be viable, especially considering that the activities necessitating the development of the resource are the very activities that may threaten it.

A protection plan must therefore be developed for recharge areas that will control the types and severity of potential hazards to their groundwater. The basis of such a plan must include delineation of groundwater recharge areas, the itemization and risk-assessment of land use activities, and the establishment of an enforceable regulatory framework.

The controllable sources of contamination result primarily from activities that occur in close proximity to the sources of water. Land uses including agriculture, mining, urban development and wastewater collection and disposal are among those whose processes have great potential to contaminate nearby water sources. Protecting the source of water thus requires the elimination, reduction or strict regulation of these processes.

In addition to land uses, it is important to note that the wells that provide the means of withdrawal provide direct access to the aquifer for contaminants if they are not properly constructed, maintained or abandoned.

2.1.1 Watershed Management and Monitoring

The provision of drinking water is first and foremost dependent upon locating a good source. Many areas of the province rely on subterranean sources, which are generally much safer in their natural state than surface waters. Protected by the overburden and bedrock, they are much less susceptible to contamination and are plentiful. The decision to obtain water this way requires construction of a well. The location and type of well in turn depends on a knowledge of the presence of water-bearing formations that will yield sufficient and safe water at a constant and dependable rate.

Hydrogeological assessments provide important details about how water cycles through an area and where it can be found in quantities sufficient to meet the requirements of whatever activities have necessitated the development of the source. They will also provide important data that will assist in determining limits on these activities in order to ensure its long-term protection and sustainability.

2.1.1.1 Hydrogeologic Assessment/Sensitivity

In a risk-assessment-based strategy for the protection of drinking water, close attention must be paid to evaluating the quality of the source. An understanding of the area’s hydrogeological processes and past and intended land uses will provide a good starting point for an initial assessment. This would be the first step in identifying potential risks and planning controls to minimize them.

This kind of information is available for most parts of the province at regional or district offices of the Ministry of the Environment (MOE), from local well contractors and some agricultural representatives. The Water Well Record, kept by the MOE, provides data on type and depths of wells in a geographical area, type and thickness of bedrock and overburden, and the quantity and quality of available water. Other sources of information include the MOE's Water Resources Reports and Bulletins, Ground Water Probability Maps and major aquifer maps. While most of this information is designed to assist in the location and establishment of drinking water sources, information covering soil types and flow rates is essential for the determination of a recharge area's natural capacity to maintain the quality and supply of its underlying groundwater. Potentially hazardous land uses can thus be suitably located to take maximum advantage of the area's natural protective properties, and properly regulated in order to avoid altering them.

A recent initiative by the province, in partnership with local conservation authorities and municipalities, if properly carried out, will apply this information to water quality concerns. The Groundwater Monitoring Network's main purpose is to ensure the protection and sustainability of the province's water resources. Components of this program include: the installation of approximately 400 electronic monitors to measure water levels in wells across Ontario; the establishment of a provincial groundwater information database; complete hydrogeologic mapping; and chemical analysis of water samples. This is an important example of the type of detailed, yet comprehensive approach that is essential for the protection of drinking water resources.

2.1.1.2 Quality (Testing & Assessment of Source Water)

Once the hydrogeological characteristics and past and present land uses of a recharge area have been determined, assessors may proceed with an analysis of the source water quality. It would be extremely costly to test for all listed contaminants for which limits have been set in all cases. A site assessment will give clues about what types of contaminants to look for, and the results will help to determine what initial controls need to be put in place, as well as the frequency and nature of subsequent sanitary surveys.

These are comprehensive surveys that would include not only a periodic evaluation of the source, but also evaluation of treatment, distribution and storage of water, as well as records, facility operations and system performance. This survey's main purpose is to identify deficiencies in the system and require their correction before they become major problems. The United States Environmental Protection Agency describes this procedure in detail and recommends that they be carried out not less than every five years. This will be expanded on in section 3.5 of this paper.

2.1.2 Land Use

Groundwater becomes polluted when runoff carries bacteria and chemicals across the ground surface into defective wells, when underground storage containers such as septic systems leak contaminants into surrounding materials, or when concentrations of pollutants exceed the cleansing capacity of the overburden. Contaminants travel with groundwater in the form of plumes. The size and shape of the plume depends on the strength and type of contaminant and the chemical and physical properties of the aquifer. The strength or level of the contaminant generally decreases the farther it gets from the contamination source, but plumes may exist over several kilometres. Potential contamination sources should always be located downslope from wells, and must be considered in the context of the local soil structure, and the volume, strength, type and dispersion of the contaminant (Salvato, 1982: 179). Because of the number of variables involved, it is always recommended to err on the side of caution when regulating the types and locations of pollution sources permitted within the recharge area.

For many communities, risks to continuing groundwater potability can be determined by the activities within the recharge area. There needs to be a full understanding of the types and characteristics of all pollutants produced by various land uses. Appropriate controls, dependant on level and severity of possible contamination, are necessary to protect the source. These controls need to have the force of law and be routinely inspected, enforced and offenders penalized for non-compliance. These penalties must be severe enough to be effective deterrents due to the difficulty and in some cases impossibility of restoring contaminated groundwater.

These restrictions must include prohibiting uses that have the potential to cause serious contamination, permitting other uses only under certain conditions, limiting density of development and regulating location within which various uses are permitted. Decisions on whether to allow certain types of industrial development or to institute restrictive agricultural or residential zoning practices must include careful consideration of the impact on the sustainability of the water source.

Microbiological contamination of groundwater occurs primarily from sewage. Septic tanks, cesspool drainage, animal waste and land application of sewage sludge are all significant sources of this kind of contamination. Residential and industrial development can be a source of contamination if proper procedure and planning for prevention of future contamination is not followed. Domestic animals feedlots are a major source of potential groundwater pollution, due in part to the large loads of organic matter and pathogenic microorganisms contained in their waste. Agriculture can also be responsible for chemical pollutants in the groundwater through fertilizer and pesticide use. Wells are a potential access point for all types of contaminants if they are shallow, poorly located, constructed and maintained, or not properly sealed.

2.1.2.1 Residential/Commercial Development

When planning for an intended use of an area of land many factors need to be considered. The impact of the proposed or existing land use on the watershed and the capacity of the groundwater recharge area are factors that need to be incorporated into the planning process. The location of wells relative to sources of contamination and any restrictions and necessary permits will play a large role in land use plans.

A typical review of a subdivision site ensures physical suitability of the area, sufficiency of water supply and waste disposal system, proper stormwater management, erosion and sedimentation control, adequacy of the street system, open space needs and proper dimension and layout of lots (Yanggen and Born, 1990, 45: 208). Local governments can also impose additional requirements for groundwater protection, such as requiring that a builder install monitoring wells and provide centralized water and sewer systems rather than individual systems (ibid.).

Integrating the natural cleansing properties of a recharge area into a development plan should always be done. For example, Riparian strips or buffer zones provide some protection of groundwater and can be employed in residential or industrial areas. The planning process should account for these zones and provide space for them. As areas of permanent vegetation and natural soil, they slow runoff, increase filtration, and filter microorganisms, nitrogen, phosphorus, organic matter and sediment from small volume surface runoff (Godwin and Moore, 1996: 5). In residential areas they provide an aesthetic and recreational benefit. It is recommended that non-vegetated areas are subdivided every acre with buffer zones, which should vary in width according to the slope of the drainage area and that strips are left relatively dense (ibid.).

When planning for settlement of an area it is important for planners to know the volume of groundwater that is available for withdrawal without depleting the resource. Matching long-term withdrawals to recharge is necessary to ensure the availability of a water source to home and property owners. The volume for both municipal and agricultural purposes can usually be estimated from readily available records (Driscoll, 1995: 840). Once the use rate is determined the annual recharge rate and the water volume in the ground need to be estimated. It is also necessary to take into consideration the decrease in recharge caused by an influx of paved and impermeable areas, which alter the inherent cycling of water within the recharge area.

When planning for well construction in a residential or developed area nearby land uses need to be taken into account. Solid waste disposal, landfills, sewage treatment facilities, industries and highways are all possible sources of contamination. Wells should be located to minimize potential impact from these activities. In New Jersey 100 water wells had to be closed due to organic pollution from a landfill. The landfill was never sealed properly and although it was only licensed to receive sewage and septic tank wastes, chemical analysis of the groundwater in the area indicated high concentration of chloroform, benzene, methylene, chloride, trichloroethylene, ethylbenzene, and acetone (ibid.: 703).

Minimum separation distances between wells and potential contamination sources are specified in Regulation 903 of the Ontario Water Resources Act (OWRA). These separation distances are actively enforced when a new well is constructed or when a new septic system is installed. Any well constructed after 1984 must have met the minimum separation distance at the time of well construction, which are as follow:

a) new dug or bored well without watertight casing to a depth of 6 metres below ground surface minimum required distance is 30 metres;
b) new drilled well with a watertight casing to a depth of 6 metres the minimum required distance is 15 metres (50 feet) (Ontario Ministry of the Environment, 1987)
c) If the direction of groundwater flow is unknown a greater distance between the well and potential sources of pollution should be required. The Ontario Environmental Farm Plan Worksheet suggests 90 metres or 300 feet whenever possible (Ontario Federation of Agriculture, 1998).

In agricultural areas the location of existing or planned structures such as feeedlots, barns, septic systems, utility lines and buildings will need to be determined before well construction begins (Fay, 1985). Property owners should drill or bore a hole to ensure the well can yield an adequate water supply, before starting construction (ibid.). A change in building plans is often a lot more feasible than locating another water source.

Considerations should also be given to possible impacts on existing local water uses when a major water well supply is being planned. The MOE administers the Permit to Take Water Program. The program requires a permit for the withdrawal of more than 50,000 litres (10,000 gallons) of water from any source including a well, with some exceptions (Ontario Ministry of the Environment, 1987: 5). The taking of water for domestic and livestock purposes does not require a permit (ibid.). The taking of water for domestic and agricultural uses are regarded as the most important, followed by municipal water uses.

The purpose of that program is to prevent water supply interference problems and to resolve them when prevention fails. If a new water well taking under permit interferes with a pre-existing water supply from an adequate well source then the permit holder is required to restore the affected supply or reduce the withdrawal so as to eliminate the interference (ibid.: 6).

2.1.2.2 Farm Practices

Many farm practices in agricultural or rural communities are potential sources of groundwater contamination. Manure handling and application, storage and disposal, and fertilizer and pesticide application are significant pollution sources in farming communities. If we consider that farms enjoy many exemptions from legislation that might affect their operations, including environmental protection, these sources become greater concerns

In Ontario surveys of farm wells (private) carried out from 1950 to 1994, detail the widespread presence of nitrate, bacteria and pesticide in groundwater. These numerous surveys indicate the extent and type of groundwater pollution present in agricultural communities in the province. Although the wells tested were private wells they encompassed a large area and can effectively tell the story of the level of groundwater contamination in rural Ontario.
The percentage of wells that contain concentrations of contaminants that exceed acceptable values for drinking water were generally greatest for bacteria and least for pesticides (Goss et al., 1998, 32: 277). In the past Ontario groundwater surveys testing for bacteriological contamination have been less common than those testing for nitrate, but recent studies show that the level of bacterial contamination (15–44 percent) is much greater than for nitrate (ibid.: 271).

From 1991 to 1992, approximately 1,300 wells were tested to produce the Ontario Farm Groundwater Quality Survey (OFGS). Of the 1,300 wells sampled nearly 40 percent contained one or more of the target contaminants above the maximum acceptable concentration (MAC) (ibid.: 278). Bacteria were the most common contaminant with 34 percent of wells exceeding the maximum number of coliform bacteria (total coliforms, fecal coliforms, and *Escheriali coli*) (ibid.).

Fourteen percent of wells contained nitrate concentrations above the limit and approximately seven percent were polluted with both nitrate and bacteria (ibid.). Six wells contained pesticide residues above the interim maximum acceptable concentration (IMAC) (ibid.).

Disposal & Handling of Manure

Drinking water contaminated with sewage is the principal cause of water-borne diseases (Salvato, 1982: 42). The principal means of preventing water-borne diseases is thus keeping the two apart. While manure is a valuable agricultural commodity due to its properties as a fertilizer, it can also be a significant source of many of the infectious agents that cause gastro-intestinal illness in humans. Safe handling, storage and disposal of manure therefore require careful consideration of potential impacts on local water sources.

Among the numerous microorganisms that inhabit the intestinal tracts of animals are the pathogens, which are those that can cause disease. *E.Coli* 0157:H:7, *Campylobacter, Salmonella, Clostridium perfringens* and *Staphylococcus aureus* are all known inhabitants of the gastrointestinal tract of cattle, and are all capable of causing severe illness in humans. The pathogens can live in water for various time periods. *E. Coli* for example can live for three to five months in a barn environment and replicate in moist conditions including surface water, water troughs and moist feed (Ontario Ministry of Agriculture, Food and Rural Affairs, 2001). In addition to the hazards presented by these pathogens, the high levels of organic matter contained in manure will also reduce the effectiveness of treatment methods such as chlorination. It is this knowledge that underscores the importance of regulated management practices for animal waste.

Ontario and Quebec produce approximately 35 percent of Canada's animal manure, half of which is from dairy cows (Dumanski et al, 1994). Livestock and poultry are essential to Ontario agriculture. Over half of all farms with $2500 in sales or more in 1989 listed livestock as their main business (Ontario Federation of Agriculture, 2000). That same year 5.7 million head of livestock and 32.1 million chickens and turkeys were valued at 2.2 billion dollars (ibid.). These numbers underscore the importance of the proper management of manure to prevent disease causing organisms and excess nutrients from contaminating groundwater. Proper storage, application and disposal are among those procedures, which need to be regulated and enforced. This is especially important considering the dwindling number and increasing size of farming operations. With more animals concentrated into much smaller areas, the volume of organic contaminants within those areas has dramatically increased. So then has the threat to local aquifers and the requirement for conscientious management strategies.

Results from the 1992 farm groundwater quality survey in Ontario show that manure storage and application are a significant factor in the presence of bacterial concentrations in wells. Concentrations above the acceptable limits were much more common on farms where manure was being used regularly for land application than on other farms (Goss and Rudolph, 1993: 126). Results also indicated that future studies on improved manure handling and strategic use of woodlots, wetlands and crop rotation schedules are necessary to protect groundwater resources (ibid. 130). Strategies for management of fertilizer applications could include development and promotion of best management practices and should focus on rates and timing of applications, and type of fertilizer applied (Rajagopal and Carmack, 1983, 8: 176).

In Ontario, the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) publishes detailed guidelines and information on environmental and nutrient (i.e. manure) management for farms. While these publications are clearly well researched and are based on sound ideas of conscientious practices, most do not have direct force of law. The statutory prevention of contamination of water by manure is left to the Environmental Protection and Water Resources Acts and, if they exist, local by-laws that govern the storage and application of livestock/poultry manure. The prohibitions contained in the Acts deal with the pollution of water in general, and do not prescribe requirements specific to agricultural operations. The by-laws are more specific, often addressing the following requirements:

a) Minimum Distance Separation (MDS) between the livestock facility or manure storage and other land uses;
b) b) Proper manure storage capacity; and
c) c) A third party-reviewed Nutrient Management Plan (OMAFRA, *About Nutrient Management and Water Qualtiy*, (http://www.gov.on.ca/OMAFRA/english/environment/facts/info_ecoli.htm) .

What this arrangement amounts to is an inadequate regulatory framework for this aspect of agriculture. A patchwork of local by-laws is not enough to protect water resources, which are not subject to political boundaries. Reliance on statutes that are not published by the ministry with primary subjective jurisdiction over farms is also inadequate. As the ministry with regulatory authority over agriculture, OMAFRA should have its own mechanisms to ensure that good nutrient management practices (NMP's) are being followed. It is worth noting that the Ontario Farm Environmental Coalition (OFEC), has developed a detailed NMP, which calls for a more active monitoring role by OMAFRA. OMAFRA would review a farmer's NMP in order to be granted a building permit to a livestock operation for either the construction of animal housing facilities or an expansion that will increase the amount of nutrients produced. The review process would include a check for compliance with minimum distance separation and manure storage sizing.

(http://www.ofa.on.ca/aglibrary/Research/Nutrient%20Management%20Planning%20Strategy/default.htm)

In response to many of the above concerns, OMAFRA last year proposed standards for agricultural operations in the province. Among the proposals are province-wide standards for the capacity and location of buildings, the storage handling, use and management of fertilizers and manure, and an enforcement framework for situations involving health and safety risks. If these proposals are based on best management practices and given the force of law, they will have a positive impact on the long-term protection of local water sources. Like the proposed Groundwater Monitoring Network initiative referred to in section 2.1.1.1, it is essential that these proposals be carefully devised and quickly implemented by the government. With proposed standards for distance separations, spill contingency plans, hydrogeological site studies, and leaching prevention, their enactment as law under OMAFRA jurisdiction will greatly enhance the protection of groundwater from the hazards of agricultural by-products such as manure. Until this is done, there will be a gap between the way manure is managed and the way it should be. Comments from the Association of Supervisors of Public Health Inspectors of Ontario (ASPHIO) are included in Appendix 2.

Other fertilizers (storage, handling, and application)

The application of municipal sewage sludge to crops is growing in popularity for Ontario farmers. It is a complex mixture of organic and inorganic compounds that are removed from wastewater streams in treatment plants. Like manure, it provides nutrients and is a source of organic material for the soil, reducing fertilizer cost and improving soil tilth (Lovell et. al., 1998). Like manure, it also contains significant numbers of pathogens, thus must be subject to the same types of precautions.

What needs to be understood here is that *unlike* manure, municipal sludge contains the residue of whatever we put down the drain, thus an additional set of potential hazards. The potentially toxic by-products of human activity that end up in the sewage stream make its disposal more problematic, thus necessitating analysis and approval processes. In Ontario before sewage can be considered a sewage biosolid and used for land application, it must satisfy the criteria outlined in the "Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land" (ibid.). If sewage meets these guidelines a proposal for land application is submitted to the Ontario Ministry of Environment. When the site criteria have been met, a certificate of Approval is granted for individual fields. For sewage to be considered suitable for land application it must have low metal concentrations and be stabilized by digestion or other acceptable means such as adding lime (ibid.). Continued research into the risks and strong regulations on the treatment, handling and ultimate use of this material are essential.

The storage, handling and application of commercial fertilizer is also an important consideration for the protection of groundwater - it should be stored more than 100 feet from any wells, and out of the way of drainage pathways. If liquid fertilizer is stored, tanks must be routinely inspected and located in a facility that would contain spills if tanks were to rupture or leak (Jones and Jackson, 1990, 45: 237). The same theory behind management practices for handling, application and storage need to be applied as with manure fertilizer.

2.1.3 Septic Systems/Wastewater Treatment

The major link between sewage disposal and public health lies with the potential for infectious organisms in the sewage to contaminate drinking water sources (Lee, 1994: ii). The proper disposal of human waste is thus an important consideration, as the human gastrointestinal tract is also a reservoir for many of the pathogenic microorganisms implicated in waterborne disease.

A direct result of residential land uses, septic systems are the most common method of wastewater treatment and disposal in rural areas. Their use is increasing as more and more rural land is being developed. These systems are engineered to incorporate the soil's natural capacity to disinfect and clean the outflow. It is therefore extremely important to ensure that the system chosen is appropriate for its location, and that it meets all design, construction and maintenance requirements.

The main function of a septic system is to retain water long enough to remove solids from wastewater and dispose of effluent to the drainfield. A septic system consists of: 1) an underground tank which holds wastewater directly from the house, where solids settle out and are broken down by bacteria; and 2) the drain field or leaching bed, which distributes the liquid from the tank over an area of subsurface soil (Stewart, 1990: 176).

Waste inside the tank separates into three layers. The scum layer consists of matter, which is lighter than water such as oil and grease, which floats on the top. Aerobic bacteria (with oxygen) break down scum (Kahn et al., 2000: 6). Sludge is the heavier solid waste that settles to the bottom of the tank, to be broken down by anaerobic bacteria (without oxygen) (ibid.). The rest is wastewater left to flow into the drainfield.

Effluent is transported to the drainfield by a watertight pipe and is distributed within the drainfield by perforated pipes in gravel. Wastewater flows through the gravel and into the soil. This area is called a biomat, a black jelly substance that forms along the bottom and sides of the trench made up of anaerobic bacteria (ibid.: 18). These bacteria consume organic material, the by-products of this which are soluble and carried away by effluent (ibid.: 19). Anaerobic bacteria allow for decomposition and therefore decrease the volume of waste. The low permeability of the biomat slows down water and allows for filtration of viruses, pathogenic bacteria and parasites

There are other types of on-site wastewater disposal systems, such as pit-privies (outhouses), holding tanks, and chemical toilets, but the septic tank – leaching bed arrangement is the most common, and is the one which most fully integrates the cleansing properties of the land in which it is laid. Sewage systems with a capacity of less than 10 000 litres per day are regulated under Part VIII of the Ontario Building Code Act (OBC) by Ontario Regulation 403/97. This sets out specific requirements for the design, construction, operation and maintenance of such systems. These requirements cover site evaluations, soil-type analysis, equipment capacities based on intended use, clearances from waterways, and operational standards, which are based on minimizing the potential health hazards. Larger sewage systems (more than 10 000 litres per day capacity) remain under the purview of the MOE as regulated by the Ontario Water Resources Act.

Until April, 1998, these requirements were spelled out in the Sewage Systems Regulation under Part VII of the Environmental Protection Act. Throughout most of Ontario, local boards of health were responsible for approvals of construction and use, and ensuring compliance with the aforementioned standards. This part of the Act has been repealed, and has reappeared as part VIII of the OBC. As a result, municipalities are responsible for the approval and inspection of these systems.

In a recent informal survey of Ontario’s 37 health units conducted by the Association of Supervisors of Public Health Inspectors of Ontario (ASPHIO), 15 of 27 respondents indicated that they are still annually contracted by their municipalities as officers under Part VIII. The other 12 had ceded responsibility to local by-law officers. In Northern Ontario, responsibility for the enforcement of this part remains with boards of health by section as stipulated in section 2.15. As the inspection and approvals process has in many cases left the jurisdiction of local boards of health, it is essential that the technicians now responsible for ensuring compliance have a good understanding of the health issues behind the requirements.

2.1.3.1 Construction

Part VIII of the OBC, whose specific clauses are set out in Ontario Regulation 403/97, is a very detailed itemization of the standards for on-site sewage disposal systems. Determination of soil percolation rates, distance to the groundwater table, intended uses and locations of structures, other waterways and other sewage or waterworks are essential to the design process. Once these have been addressed, a sewage disposal system must be appropriately located, and built using prescribed materials to prescribed specifications. The technicians involved must be licensed, and the system must be inspected before the components are buried. This is an example of the types of multiple safeguards that are essential to the prevention of contamination.

2.1.3.2 Approvals

Depending on the stage of development appropriate controls must be established for septic systems such as: during land use planning, during subdivision planning, when the septic system is designed, approved and built, and during the operation of the system. Close attention must be paid to the results of preliminary site assessments and the plans for the system to ensure that the design is appropriate for the site and its uses.

Prior to 1998, any person installing a septic system in Ontario had to obtain a Certificate of Approval from the MOE and have the system installed by a licensed contractor (Government of Ontario, 1998). A Use Permit was required before the system was out to use, after a final inspection and assurance that full compliance with all regulations was achieved. With the regulatory authority change, municipal building permits replaced Certificates of Approval and Use Permits, which has obscured the links between these systems, the local water source and human health.

In order to compensate for the loss of health –related expertise from the approval and inspection of these systems, local boards of health should continue to be involved in the approvals process, and should be notified of any new construction or alteration of existing systems. This will ensure that records exist for all systems, and that a verification process exists to identify potential problems before they arise, from the perspective of protecting health.

2.1.3.3 Maintenance

A major advantage of septic systems is low maintenance. Septic tanks are low cost, low maintenance and low technology compared to municipal treatment plants (Stewart: 177). However, existing responsibility for operation and maintenance of the septic system lies with the property owner. It is therefore essential that the owner be aware of his or her obligations after the installation of the system.

Septic systems accumulate material that needs to be pumped out at standard intervals. If it is not pumped the sludge will reach the outlet level and begin flowing into the leaching bed where it will plug the pipes. Wastewater should remain in the tank for at least 24 hours, but ideally two to three days. As sludge and scum accumulate they take up space in the tank thereby decreasing retention time. If the tank is not pumped regularly the wastewater will not spend enough time in the tank to settle out and separate. Solids will flow into the drainfield and the biomat causing excessive growth and reducing biomat permeability (Kahn et. al.: 22). The biomat will grow too thick and water will pond in trenches or above the ground in the drainfield, and backflow into the septic tank and even the house (ibid.). As well raw sewage and possible toxic chemicals will drain into the soil, contaminating anything in its way, such as wells, streams, or lakes. It is recommended that septic systems be checked every two years.

Different types of septic systems require different kinds of maintenance. It is important that individuals responsible for the systems know and understand the required maintenance of their particular system and the health-related reasons for it. Inspection and enforcement by outside agencies is needed to ensure that system owners are complying with laws, and educational mechanisms must be in place to maximize the owner’s knowledge of responsibility. Public health departments are a logical source for this type of information, but it must also be readily available from contractors, the MOE, and Ontario Building Code inspectors.

2.1.4 Wells

In addition to controlling the sources of polluted runoff, wells need to be regulated. Well regulation serves to protect human health by ensuring safe drinking water and to protect groundwater resources, which are susceptible to contamination through defective well construction and care. Pollutants can enter groundwater through improperly sealed wells, cracks in casing, abandoned wells that were not properly sealed, or wells located in close proximity to a contaminant source, or in an area susceptible to contamination.

2.1.4.1 Construction

Before a well contractor is hired or drilling begins, the location of existing or planned surface or underground structures such as buildings, septic systems and utility lines should be established. A well should not be located in an area where it is difficult to maintain, repair, test, or inspect (Fay, 1985). When choosing a site for a well it is important to account for potential contamination sources. A site should be located up slope from potential sources of pollution, such as septic tanks, outhouses, barnyards and manure storage areas, and not between streams and contamination sources (ibid.). Bacteria are less likely to be transported from the ground surface to the water table by natural flow than by direct access by improperly sealed, abandoned or unused wells (ibid.).

In Ontario, Regulation 903 respecting Wells, made under the Water Resources Act, sets out standards for licensing of technicians, construction and location requirements, record requirements, maintenance and abandonment. The requirements are partly designed to prevent the entry of contaminants into the aquifer via the well. Common causes of bacterial contamination of wells include improper sealing of the annular space (i.e. the space between the outer edge of the drill-hole and the well casing), improper, damaged or submerged well head seals, proximity to contamination sources – alone or in combination. Close adherence to the prescribed requirements by technicians with the appropriate expertise will exclude these causes. Comments on this regulation provided by the Association of Supervisors of Public Health Inspectors of Ontario are included in Appendix 3. alPHa is also in the midst of preparing recommendations for the provision of safe water and the prevention of disease from private wells.

2.1.4.2 Approvals

As with septic systems appropriate controls are very important. Land use planning, subdivision planning, choosing a well type, hiring a well contractor, well construction, maintenance and abandonment and usage are all stages requiring regulation. Many risks and potential problems can be identified in the planning stages, which minimizes burden if changes must be made. An approval process serves this purpose.

In Ontario before well construction begins, a Permit to Take Water must be obtained under the OWRA for the taking of over 50,000 litres per day (with the exception of farming uses). Issuing and recording such permits contributes to the database of information on groundwater use in a given area. It also requires consideration of local influences and impacts, and requires the owner to undertake monitoring and record keeping, subject to MOE inspection. In addition, renewal requirements ensure that the information is reviewed every five to ten years. Domestic uses fall far below 50,000 litres a day and therefore do not require a permit to take water. What this means is that wells constructed for the private use of the owner on whose property it is constructed are not subject to the same types of routine safeguards. This becomes a concern considering that while the well itself may not be shared, the source water likely is.

It should be required that *all* person(s) planning for the construction of a well obtain a permit. A Certificate of Approval could be obtained before construction, and a Use Permit could be issued after a compliance inspection. This would ensure that all wells are constructed according to specifications, that well owners are more completely educated on maintenance requirements, and that a more complete record of access points to the aquifer. This would aid in keeping track of all withdrawals and estimated amounts in an area. It would help to prevent future interference complications. It would also prevent the exacerbation of the current problem of not knowing the location of abandoned wells, whose perils are addressed in a later section.

Requiring permits for all wells could also facilitate a routine inspection program whereby an employee of the MOE inspects a well at appropriate intervals to ensure a continued state of good repair. Every well has the potential to be a source of groundwater contamination if not maintained properly. The well owner would be responsible for correcting any defects before renewal of permits or to avoid fines and other legal action.

2.1.4.3 Maintenance

Section 20 (3) of Ontario Regulation 903 states, “the well owner shall maintain the well at all times after the completion date in a manner sufficient to prevent the entry into the well of surface water or other foreign materials.” (R.R.O. 1990, Reg. 903, s.20). With the onus placed squarely on the owner, it is important that he or she have the knowledge required to do so.

Owners of larger communal systems, by virtue of the approval process, monitoring requirements and so on will likely have this knowledge. The private well owner on the other hand, will not necessarily be as well versed, despite being responsible for preventing his or her well from becoming an entryway for contaminants. The permit and approval process proposed above for *all* wells would give authorities the opportunity to educate new owners on troubleshooting and inspection. When the owner is given the means to recognize problems with the well seals, casing, annular space, air vents, accessibility, and surface water drainage, yet another small but significant measure for the protection of groundwater is put in place.

2.1.4.4 Abandonment

Section 21 of the regulation also gives the well owner responsibility for the proper abandonment of wells (R.R.O. 1990, Reg. 903, s. 21) An abandoned well is a well that can no longer be used as a potable source of water supply or is so damaged it cannot be used to obtain groundwater. The regulation requires that when a well is abandoned it is to be plugged with concrete or a suitable material so as to prevent the vertical movement of water or gas in the well between aquifers or between an aquifer and the ground surface (ibid.).

Improperly abandoned wells are dangerous to public health and safety. An abandoned well must be properly sealed to prevent groundwater pollution, conserve aquifer yield and artesian pressure (particularly in the case of flowing wells) and to prevent poor quality groundwater from moving between water bearing zones.

Because proper sealing of a well requires a certain degree of knowledge about how it was constructed in the first place, it is recommended that a well contractor familiar with proper abandonment procedures be hired. Otherwise, information on the proper procedures should be available from the MOE.

While the regulation sets out the requirements for abandonment, it does not prescribe any type of verification function. If a licensed contractor (who could certify in writing that the well has been properly sealed) is not employed, there should be an inspection requirement to confirm and record proper abandonment. An important side effect of this would be a record of all abandoned wells in an area. Because these requirements do not exist, many Ontario aquifers may be at risk due to unknown numbers and locations of improperly decommissioned wells.

2.2 Control of Health Hazards

Once the source water has been assessed, past and present land uses have been itemized, the decision to take water has been made and potential hazards have been identified, strategies to protect the source water must be implemented. Many of these strategies stem from advance planning for the development of a water supply and for the land use activities that require it. These have been detailed in the previous sections and summarized below:

1-Watershed management
Health hazard control strategies are based on knowledge of local aquifer and recharge area characteristics. Assessing the source water to ensure its safety and an adequate supply is the first of these controls. Knowledge of the broader cycles that sustain the supply will identify the limiting factors for the activities for which the water is needed. Careful planning will integrate the natural processes that sustain the water supply and ensure that development has as little impact on them as possible. Overwhelming these natural processes increases risks to the water and therefore human health. Prohibiting, limiting and regulating activities with such potential are thus broad health hazard controls that provide an important barrier to a host of possible risks.

2-Land Use.
When considering the idea of source water protection, it must be understood that it means protection from the by-products of human activity. As soon as human activity presses a given aquifer into service, the aquifer is at higher risk. It is with this in mind that specific controls over land uses must be implemented. Retaining the infiltrative capacity of local soil, environmental controls over toxins, proper waste management, and planning minimum distances or barriers between sources of contamination and pathways to the water source are all controls that have been addressed above.

3-Wasteawater, Sewage, Manure
These are the major sources of potential contamination of water in rural areas. The importance of separating human and animal wastes from water sources has been known for a very long time. Some will even argue that this was the original public health practice. Safe storage, handling and disposal of manure, and careful septic system design and maintenance are absolutely imperative barriers to the entry of harmful pathogens into the water supply.

4-Wells
The construction of a well provides access to the groundwater supply. This means two things – that water can be drawn from the aquifer, and that there is a direct pathway from the surface to the water source. It is thus extremely important that wells be properly approved, constructed, maintained and decommissioned.

Taken as a series of strategies with the same goal, these controls amount to a comprehensive overall strategy for the protection of source water. Decision-makers involved in this strategy should include conservation authorities, provincial and federal governments, municipalities, and watershed residents. The protection of the groundwater source is the first of a series of barriers that ensure clean drinking water. Because it is in everyone's interest to protect drinking water and because fixing problems is generally more costly than preventing them, this step is of paramount importance. In order to ensure that proper decisions are made when devising strategies for source protection, a legal framework must be provided by the governing bodies with jurisdiction over it.

Under the provisions of the Constitution Act, responsibility for water is divided between the federal and the provincial levels of government, depending on the context. Provinces are designated as the owners of water resources, thus have legislative authority over use, development and pollution control. Federal responsibilities cover aspects of water that have potential for national economic impact and certain specific aspects of environmental protection. Both levels share responsibilities for agriculture, health and ensuring the provision of a safe and sufficient supply of water for all Canadians. Each is thus enabled to enact legislation for the general protection and sustenance of water resources.

The Canada Water Act for example calls for joint consultation between federal and provincial governments on issues related to water resources, and several policies are published to address the various objectives that must be met for the provision of safe water. The **Federal Water Policy (FWP)** addresses management of water resources for the purpose of protecting and enhancing the resource by “anticipating and preventing the contamination of all Canadian waters by harmful substances.” It includes strategies for integrated planning and development, legislation for the management of toxins, public awareness and transparency on the state of the environment.

The Groundwater Contamination Statement, made under the FWP, recognizes the need to upgrade databases on groundwater in order to develop meaningful guidelines for groundwater assessment, protection and management. The Safe Drinking Water Statement recognizes the shared responsibility of federal, provincial and municipal governments in its provision. It addresses the need for well-researched and consistent standards and promotes the need for public understanding of critical issues around safe water. Specific health hazards are identified by the Canadian Water Quality Guidelines and the Ontario Drinking Water Standards, which identify hazardous substances that might be found in water and establish limits on them, based on current knowledge of their adverse health effects.

The identification of responsibilities and the drafting of such policies and guidelines indicate that there is an awareness of what needs to be done and who needs to do it to protect drinking water, but this awareness must be acted on to be of any use. This action involves many stakeholders (industry, researchers, legislators, the public, conservation authorities to name but a few), requires monetary and human resources that are not always available, and involves co-ordination of effort that is not without its own obstacles. In Canada, only Manitoba, New Brunswick, Newfoundland and Nova Scotia have enacted specific legislation allowing for the creation of protected watersheds or wellfields (Christensen and Parfitt, 2001: 26).

Government Initiatives for Source Protection - Two Cases.

The Wellfield Protection Program in New Brunswick is available under the Clean Water Act. The program identifies wellfields as protected areas and “controls the kind and quantity of chemicals being released, stored or used in that area” (New Brunswick Department of

Environment and Local Government, 2000). The Clean Water Act provides the regulatory framework for the Wellfield protection program. Section 14 of the Act allows the Minister of the Environment to designate protected areas once they have been identified (Ibid.) Within each protected area the minister can designate the use of water, regulate or prohibit land use activities that may cause groundwater contamination, and establish and enforce guidelines and standards to protect the water supply (ibid.).

The Wellfield Protection program divides the protected field into three concentric areas around the well, A, B and C. Three categories of groundwater contaminants are then considered: bacteria and viruses; petroleum products; and chlorinated solvents. The different lengths of time these contaminants take to biodegrade naturally in the environment will then aid in determining where in these areas their sources should be located in relation to the wells(ibid.).

The size of areas A, B and C are determined by local groundwater travel times of 100 to 250 days, 250 days to 5 years and 5 to 25 years, respectively (ibid.). Any potential contaminants in these zones must therefore naturally degrade within these time periods, before the water carrying them reaches the well. This will in turn determine the types of controls that need to be placed on activities within these areas. Some activities will be permitted, some only under certain conditions and a others prohibited altogether within the protected area based on their potential risks (ibid.). This protection program is designed to complement and strengthen other measures such as the Petroleum Storage and Handling Regulation, the Pesticides Control Act and technical approval processes. It is a proactive approach to managing all chemicals within the recharge area of a wellfield for the purposes of minimizing health hazards and costs associated with contamination cleanup.

Another example of government-initiated water protection comes from the United States, where approximately 80 percent of the community water systems rely on groundwater – a percentage that underscores the vital importance of protecting these resources. Congress has enacted a series of laws to regulate contamination at the source. (United States Environmental Protection Agency [US EPA], 1999:13). The Sole Source Aquifer Protection Program established by the Safe Drinking Water Act (SDWA), in 1974, allows the public to petition for protection of an aquifer that is the sole source of drinking water for the local population. To qualify the aquifer must provide over 50 percent of the population with its primary source of water (ibid: 14). Once designated, the EPA has the authority to review federally financially assisted projects that may contaminate the aquifer. If there is a potential for contamination the EPA must work with the project leader and associated federal agency to recommend protective measures (ibid.: 15). Since the first sole-source aquifer designation in 1975, 70 aquifers have been designated in 25 states and territories (ibid.).

The examples above serve to indicate that the protection of source water depends on carrying out the roles and responsibilities of government agencies at all levels and in several disciplines. The interconnections among ecosystems and all of the activities that take place within them must be carefully studied in order to identify the potential threats to drinking water. Once done, effective strategies based on local conditions can be implemented to minimize these threats.

2.2 Monitoring Criteria

The identification and control of health hazards is an important initial step, but it is also an ongoing process. To ensure that source water is fully protected there is a need to make sure that all strategies designed for the protection of the groundwater resources are appropriate and effective. This requires monitoring protective systems to identify and correct exceedances and incidences of non-compliance. Monitoring serves to warn of future problems and makes it possible to mitigate them before they develop.

Once the initial site assessment of an area is complete, prevalent contaminants will determine what needs to be tested for and how often. These are the monitoring criteria to be established in order to identify changes in the health hazard profile of the local source water. When properly followed, new or increased health hazards can be quickly identified and control measures altered accordingly. Recording the results of monitoring protocols allows the identification of seasonal or long-term trends and inconsistencies. A good historical record will also identify the impacts of new land uses or fundamental changes in existing ones. The sudden expansion of an agricultural operation, for example, may add new pressures to the ecosystem, the impacts of which can be measured by the monitoring process..

Ideally, the monitoring protocol will be set up to identify changes in contaminant levels before they reach their prescribed limits. A steady increase of contaminant levels for example might provide enough clues to their source that measures might be implemented to stem their flow. Monitoring the source water itself should complement the observation of activities in the area that are sources of these contaminants. This observation should take the form of regular inspection of regulated activities and enforcement protocols that will ensure the proper management of hazardous by-products of these activities.

Routine monitoring of water quality in domestic and municipal wells drilled into a given aquifer is the most effective way of ensuring that the source water meets prescribed health-related parameters. For example, a significant total coliform level in a farm well may indicate that minimum distance requirements are not being met, or that manure is being managed without using best management practices (i.e. proper application timing, storage or overuse). If this is the case, authorities may educate the farmer on good management practices, or take legal action as the case dictates. Monitoring thus identifies a problem, gives a clue to its source, and provides an opportunity to correct it before it does significant damage.

As the source water is monitored, so should be activities in the recharge area that may impact it. The OMAFRA and OFEC have designed best management and nutrient management practices as outlined previously in this paper. A compliance list of best management practices suitable to local conditions needs to be drawn up, and made available. Soil tests on local farms allow for monitoring of NMP suitability. This kind of monitoring must also account for changes in practice, therefore must be routine. They should also be mandatory, which will require the implementation of OMAFRA's proposed agricultural standards as outlined above.

Assessment of the source and contaminants produced in the area will also be needed to ensure that the type of treatment at the water plant is appropriate to disinfect the water. Ontario's new

Drinking Water Protection Regulation prescribes minimum treatment requirements, but also provides for exemptions. Water providers may apply for to the MOE for a variance, which if approved, removes the obligation for the disinfection of their groundwater in the distribution system. Given the mounting evidence that groundwater is subject to contamination as soon as it is put to use, it is our position that minimal disinfection must be required in all cases. If the exemptions are allowed to remain, strict guidelines for granting them must be employed.

2.4 Contingency Plans

When source water protection fails and a contamination incident occurs there are some procedures in place that must be followed. In Ontario provincial law requires that all spills or accidental discharges must be reported immediately to the ministry of the environment via the spills hotline. This responsibility belongs to the person who causes or permits the spill and those who had control of the material when the incident occurred.

The MOE's Spills Action Centre (SAC) provides a province-wide toll free system staffed by environmental officers 24 hours a day. They have the responsibility of initiating and coordinating an environmental response to reported incidents. Staff members have access to chemical databases and can provide expertise and advice over the phone. Of the four to five thousand reports of spills annually, most can be dealt with by those responsible for the spill or by local municipal agencies without the on-site presence of ministry staff (MOE, 1998).

In the event of a serious spill or emergency SAC can initiate a level one, two or three emergency, in which case a response can be expected within six hours or less depending on the level and type of emergency (ibid.). Samples taken by field staff from spill sites are analysed by ministry laboratories in Toronto (ibid.). It is important to obtain fast and accurate information to initiate appropriate response procedures and cleanup actions. A clear reporting system is thus essential to ensuring that if a spill does occur that it can be contained before causing extensive damage.

When spills occur it is the responsibility of the owner and the person who had control of a material at the time it was spilled to immediately move to contain the spill and take corrective action. If, for example, a spill occurs on a farm, OMAFRA will take the lead to ensure that the corrective actions are carried out. If the spill spreads via a well or waterway or other method beyond the farmers land and control, OMAFRA will cede the lead role to the MOE but remain available for technical support and advice. The Environmental Protection Act gives the ministry the authority to order the responsible parties to clean up the site to ministry guidelines. Should these guidelines fail to be met the ministry take action itself, recovering the costs from the owner. If a spill is serious enough that it threatens the viability of a water source, these responses must be complete and immediate. Resources must therefore be committed to ensuring that if these responses are necessary, that they are effective.

If the above contingencies fail, the possibility of contamination and temporary or permanent loss of the local water supply becomes real. Finding a new well water source is not often easy to do. In some cases, it is not an option at all. While having a contingency plan for dealing with extraordinary contamination of the local water source is an essential part of the quality assurance plan, proper source protection measures must be planned and implemented to ensure that it never has to be invoked. As complete as a contingency plan may be, it is not guaranteed to reverse the results of the failure of those protections.

2.5 Verification System

Regulating land use is an integral part of preventing groundwater contamination. Groundwater recharge zones must be protected not only by prohibitive or restrictive legislation, but also by the verification system that is enabled by the legislation to ensure compliance. This involves education, deterrence and enforcement.

Livestock farming for instance should have further restrictive and regulative requirements. Without them, there are fewer opportunities for education and no opportunities for effective legal action. Existing livestock farms operating on aquifer recharge zones should be required to follow a set of mandatory best management practices aimed at reducing contamination of groundwater. The farmer needs to be aware of these practices, and of the environmental and legal implications of ignoring them. Routine inspections of farms and evaluation of management plans would give provincial authorities the opportunity to identify problems, give the operator the opportunity to correct them, with the understanding that failure to do so will result in a stiff penalty. In British Columbia, there are inspection teams who visit farms to ensure compliance with relevant regulations. The teams are made up of farmers with expertise in what to look for. Those cited for violations are given six months to adopt measures to follow regulations. Enforcement is handled directly by the Ministry of the Environment.

Municipal by-laws often govern the storage and application of livestock and poultry manure. The Ontario Building Code and the National Farm Building Code regulate design and construction of storage units. The Farming and Food Protection Act, The Environmental Protection Act, Water Resources Act, and the Pesticides Act all have regulations aimed at the protection of groundwater resources.

The MOE under the OWRA regulates the water well industry in Ontario. Regional Staff of the MOE are required to see that the Act and all regulation pertaining to groundwater supplies are enforced equally across the province. Regulations include licensing a well contractor, hiring a well contractor, minimum distance separation, maintenance, and plugging abandoned wells. Verifying compliance with these requirements requires inspections. Non-compliance should result in notification of improvements that must be made, of re-inspection and of possible fines if they are not carried out.

The OBC and its appurtenant regulation (O. Reg 403/97) set out criteria for the design and installation of small septic systems. A licensed contractor must install the system after a building permit is issued. A regular maintenance contract is required of the owner to ensure that the system is operating correctly (O. Reg. 403/97, Part 8). It is up to the owner of the system to notify the chief building official if required service is not carried out, or if there are any changes in the contract under which the system was put to use. A license renewal process would ensure that all information on the system is current and in the hands of the regulatory agency, whether it is the municipality, the health unit or the conservation authority.

The appropriate combination of permits, licenses, record-keeping and routine inspections constitutes an effective verification process. Inspectors designated by legislation governing various land uses, farm practices, wells, septic systems and general environmental protection together verify that the protective systems that ought to be in place in fact are. For the system to be effective, the verification functions enabled by statutes, regulations and by-laws should be mandatory and of appropriate frequency. This function, like monitoring, serves to identify situations that might evolve into real threats to source water before they have the opportunity to do so.

3.0 DISTRIBUTION SYSTEM

The provision of safe, high quality drinking water will often depend on a well-constructed, well-monitored and well-maintained distribution system. The distribution system refers to everything from the intake of water into the waterworks until the water exits the consumers tap. This includes all the processes acting on the water while in the plant; testing and monitoring of the water before it exits the plant; the maintenance and monitoring of the water while travelling through the distribution system; and the maintenance, and monitoring of the system itself from one end to the other. In addition the stages of development of the waterworks must be taken into account along with the provision of policies, procedures, emergency plans and credibility of employees.

System size and complexity will vary with the general rule that smaller communities, especially those relying on groundwater, will have smaller, simpler systems. However no matter the size or scale of operations all steps must be carried out to ensure that the public receives a safe and potable water supply.

3.1 Risk-assessment and hazard identification

The delivery of quality drinking water depends on a well-engineered and maintained distribution system. In order to satisfy quantitative as well as qualitative demands, requiring detailed plans of the entire system to be available to all appropriate agencies is essential. Considerations should be given to what types of materials are permitted, and written policies and procedures for monitoring, maintenance and contingency plans should exist. In order to minimize potential health hazards at this point, an examination of intended design, use, materials and capacity should be carried out. Approval would be given once the issuing body is satisfied that the design, materials, maintenance, policies, procedures and proposed contingency plan are adequate for the provision of safe and sufficient potable water to those served by the system.

One of the most crucial components of proper planning and evaluation of the distribution system is a detailed examination of the types of information considered in the preceding section. The quality and quantity of the source water, an inventory of all land uses and their locations, wells and wastewater systems will be invaluable information for an assessment of the distribution system itself. Testing and monitoring requirements in particular should be based on local conditions. The hazards that threaten source water are, under the right circumstances, the same ones that might threaten it in the distribution system. Being aware of existing risks allows for their management in the planning stages.

As the natural cleansing capacity of the soil can be overwhelmed by gross contamination, so can the cleansing capacity of treatment strategies that might be part of the distribution system. The distribution system must thus be designed to prevent such contamination by using proper materials and implementing appropriate maintenance, treatment and monitoring strategies.

It is important to note that these systems can be quite large, incorporating kilometers of underground piping, screens, backflow-prevention mechanisms and valves that are not easily accessible for the purposes of maintenance and inspection. Having detailed plans of the system that include specifications on materials used as well as dated records of construction, maintenance and replacements will assist in the planning of upkeep. Knowing for example the age and composition of a pipe, as well as the quality of water flowing through it and the types of materials around it will allow operators to estimate its working life. A broken underground pipe is an access point for any bacteria in the soil surrounding it.

In Alberta, drinking water systems require provincial approval pursuant to the potable Water Act, which contains standards for the design, construction and operation of these systems, must be adhered to (Christensen and Parfitt: 31). Ontario has a similar approvals process, but it is based on review of plans in the absence of binding standards for design, construction or materials (ibid.). Guidelines for design and materials for water system components are however available under the National Plumbing Code of Canada, the Canadian Standards Association, Underwriters Laboratories of Canada and the American National Standards institute.

3.2 Control of Health Hazards

The protection of the source water is very important for a safe drinking water supply. However contamination still occurs and even with the nature of groundwater it is not possible to guarantee uncontaminated water from the source. Once drawn from the source, the delivery of safe water to the customer depends on the monitoring for biological and physical indicators on a frequent, routine and long-term basis to detect the presence of contaminants, and treatment strategies to eliminate them.

It is important to have information regarding the land use in the recharge area. This will determine the types of contaminants to be included in the monitoring protocol and the level of treatment necessary at the waterworks plant. A deep drilled well for example may require only minimal chlorination. A shallower well that has often shown presence of coliform or other contaminants might require a higher level of chlorination and more frequent monitoring. A ground water source that is known to be influenced by surface water might also require filtration to remove chlorine-resistant cysts and organic matter. It is also essential to keep informed on new research into safe, affordable and effective treatment methods, some of which are discussed below.

Monitoring protocols will also depend on an initial analysis of local conditions. For the types of waterworks under consideration here, testing for all contaminants listed in the Ontario Drinking Water Standards would neither be productive nor cost-effective. The initial risk-assessment allows for the identification of existing and potential hazards to drinking water, which in turn allows for the tailoring of a local monitoring program. Ongoing monitoring of changes in local land use activities will also be an invaluable tool for ensuring that emerging hazards are always accounted for and safeguards altered accordingly. This type of monitoring should be part of the periodic sanitary surveys described in the preceding section.

The application of the above treatment and monitoring strategies occurs mostly within the water plant itself. The treatment and monitoring technologies are generally located within them, for the purposes of ensuring that the water leaving the plant is potable even if the water coming in is not. It is important to remember that water must still travel a fair distance before reaching the tap of the consumer, during which time its quality can deteriorate. The loss of disinfectant strength of chlorine over time, the potential growth of bacteria, and contamination from the piping materials due to corrosion during the transportation process are all possible causes of concern in the delivery system. Accidental intrusion of pollutants is also a potential source of contamination and can occur at any time or place in the distribution system. Monitoring the distribution system between the plant and the properties it serves is thus essential to the timely identification of any of these situations.

Taking samples to measure the chlorine residuals at locations far removed from the treatment plant is an example of this component of a complete monitoring system. The potential for bacteria to regrow in pipes carrying water through the distribution system is regarded by health officials and many water providers as a possible source of disease outbreaks. A sufficient level of chlorine will kill most of the pathogens that are transported by water. Chlorine loses its effectiveness over time, which means that while levels sufficient to kill pathogens may be present as the water leaves the plant, this may not be the case by the time it reaches remote portions of the piping network. A monitoring protocol that accounts for this will allow operators to take appropriate measures to ensure that effective chlorine residuals are present in all parts of the system.

Public health depends on the quality of water coming through the tap. There needs to be a thorough system of testing and monitoring from the entry of water into the waterworks plant until it is piped into the consumers home. It is the responsibility of the waterworks owner to ensure that a safe drinking supply is maintained in the distribution system. Based on a proper understanding of contaminants and treatment methods, appropriate operating, testing and treatment protocols must be in place. Written policies, procedures and contingency plans to deal with water quality problems and staff must be appropriately trained to carry out their duties. Inspections and regulations by an outside body are needed to ensure that these duties are being properly carried out. Province wide standards for training and certification of staff and must be implemented and enforced. Lines of communication from the plant to health and environment authorities, municipalities the customer must always be available and fluid to ensure that the appropriate parties are quickly informed of any potential problems.

3.2.1 Contaminants

Contaminants can be divided into three primary categories: Microbiological, chemical and physical. The sources, health effects, permissible concentrations, and control measures differ for each. In groundwater supplies in rural areas, bacteriological contaminants are of primary concern to public health, though and physical and chemical contaminants must also be addressed.

3.2.1.1 Microbiological Contaminants

Bacterial pathogens are significant agents of infectious diseases and are ubiquitous in the environment. Mammals (including humans) for example are colonized by many different types of bacteria. Most are harmless, but some have the potential to cause serious adverse health effects if given the opportunity. Most of the infectious agents of concern are residents of the intestinal tracts of these mammals, entering the environment with their waste. This is the first step in a possible pathway for the infectious agent to cause disease. Pathogens of note include (but are not nearly limited to) bacteria such as *Salmonella, Campylobacter, Shigella, E.Coli* and *Clostridium* protozoa such as *Cryptosporidium* and *Giarda* and viruses such as Hepatitis A. These all have different effects, but their mode of transmission (fecal-oral) is the same. Broad-based strategies to prevent contamination of groundwater in general will therefore prevent the entry of these organisms into their infectious pathways.

When microbiological contamination occurs in water supplies it may have come from a number of sources. Septic systems and cesspools are often the cause. Domestic feedlots, manure storages, and areas of application can lead to polluted runoff if proper farm management is not adhered to. Improper well construction and care allow contaminated runoff to enter the well.

Contamination of groundwater supplies by animal feces has been implicated in cases of E. coli infection worldwide (Jones, 1999,15: 80). *E. coli* is present in the gut of most mammals and does not harm the host. However strains of *E. coli* are host specific and strains in the gut of one species can be fatal in another. *E. coli* 0157:H7 for example resides in cattle with no adverse effect but in humans this strain is highly infectious and produces lethal toxins (ibid.). In children under five and the elderly, the infection can lead to hemolytic uremic syndrome in which red blood cells are destroyed and the kidneys fail. Only small amounts of these bacteria are needed to infect humans and approximately two to seven percent of those infections lead to hemolytic uremic syndrome (ibid.). In the United States it is the principle cause of acute kidney failure in children and most cases are caused by *E. coli* 0157:H7 (ibid.: 82).

In addition to preventing contamination, simple treatment methods such as chlorination are effective in eliminating these organisms from the water supply. In the United States between 1971 and 1982, 51 percent of reported waterborne disease outbreaks were caused by contaminated groundwater that was not disinfected or inadequately disinfected (Stewart, 1990: 81).

Infectious organisms present in water are difficult to isolate and identify and complete analysis would not be practical in terms of time and money spent (ibid. 82). In order to bypass the expense and effort of trying to monitor individual pathogens in water, a category of bacteria has been chosen as indicator organisms. When present in water above specific concentrations, bacterial indicators such as total coliforms, fecal coliforms and fecal streptococci suggest that recent contamination with fecal matter may have occurred and there is a good chance of pathogens transmitted by the fecal-oral route also being present. High counts of these indicators thus translate as an unacceptable risk of disease.

3.2.1.2 Chemical Contaminants

Chemicals present in water are wide ranging and can come from a variety of sources. Agricultural practices and septic systems are the most prevalent producers of chemical contaminants in rural systems. Chemicals of concern are synthetic organic chemicals, (SOCs), which are man-made chemicals containing carbon. Biological or natural systems do not have the ability to degrade or break down these chemicals (ibid. 129). Once in the groundwater system these chemicals are transported quickly with little to no retardation or degradation (Driscoll: 816).

SOCs can lead to numerous adverse health effects, depending on the specific chemical. The effect of a particular SOC on human health will depend on its toxicity and the level of exposure. Pesticides and herbicides used in agricultural operations are SOCs. Health effects caused by pesticide exposure include cancer, birth defects, Parkinson’s disease and other genetic, reproductive and central nervous system abnormalities (Stewart: 149).

Septic tanks can also be a source of SOCs. SOCs are found in hundreds of household products and it is not uncommon for people to dump these products down the drain. They not only contaminate groundwater they also corrode pipes leading to the release of more organic chemicals from leakages. Pesticides, paint products, cleaners, septic tank cleaners, and auto products are all products containing SOCs that there is a strong chance of being flushed down the drain.

Septic tanks and agricultural fertilizer are also both major contributors to nitrate levels in groundwater which as previously explained high levels of exposure to can lead to methemoglobinemia, a condition in babies where the blood cells are depleted of oxygen. High nitrate levels have also been implicated in certain types of cancer, but drinking water is not the primary source of dietary nitrates.

Trihalomethanes (THMs) are a by-product of chlorine disinfection and are a volatile lightweight SOC further explained in the water treatment section.

Acceptable health-related limits are published for each of these and many other chemical contaminants under the Ontario Drinking Water Standards. The frequency with which they are monitored should be based on the risk assessments addressed above. Evaluation of chemical contaminants is an essential component for a complete approach to water safety, the details of which are outside of the focus of this paper.

3.2.1.3 Physical Contaminants

Turbidity, or cloudiness, is not common in groundwater due to the natural cleansing processes acting on the water. Turbidity refers to the solids and organic matter that do not settle out of water. The main concern with turbidity is the interference with the disinfection process. In turbid waters nutrients can adhere to particles and therefore act as a nutrient source for waterborne bacteria, protozoa, and viruses (Christensen and Parfitt: 21). Microorganisms become obscured by the particles they are attached to and this makes it difficult to determine the type of microorganisms present (ibid.).

When chlorine is added to turbid waters additional health risks arise. Chlorine can bind to organic particles forming carcinogenic by products known as trihalomethanes (THMs) (ibid.: 10). These physical contaminants are thus not necessarily health hazards in themselves, but can provide conditions that increase the risk to health. The simplest method of dealing with physical contaminants is to filter water before treatment by disinfection.

3.2.2 Treatment Methods

Surface waters are subject to a much greater quantity of contaminants than groundwater and almost always require other forms of treatment in addition to disinfection. Groundwater supplies under the influence of surface water or contamination from land uses, need to be subject to the same rigorous treatment standards as surface waters. Those groundwater sources not under the influence of surface water in the past and currently in some cases have gone untreated and are safe for human consumption. However with the increase of population density, and farm size and operation capacity comes an increase in the possibility of contamination of groundwater supplies. The risk to human health has forced reconsideration for the need for some form of treatment.

In the treatment of groundwater supplies chlorination or another method of disinfection is often enough to effectively treat water provided other safeguards are in place. However in some cases it may be necessary to have a two-step process of filtration and disinfection for effective treatment of water and to remain on the side of caution.

In Ontario as of December 31, 2002, under the new Drinking Water Protection Regulation (DWPR) chlorine or another equal or greater method of disinfection as a minimum treatment must disinfect all drinking water entering the distribution system. Surface waters must be filtered and disinfected as a minimum level of treatment. Systems relying on groundwater must be disinfected but can apply for an exemption if stringent requirements are met. Variances from disinfection of groundwater supplies will be considered on a case by case basis with specific requirements.

The characteristics of raw water should determine the method of treatment. The type of treatment chosen should be site specific and should depend on results of initial chemical, physical and microscopic examinations (Salvato: 257). Disinfectant dosages need to be determined by the extent of pollution of source water, type of microorganisms and other contaminants likely to be present, pH of the water and other treatment water receives.

In the United States, under the SDWA the EPA is required to specify the “best available technology” for treating each contaminant for which EPA sets an MCL. The EPA defines a “best” technology for all of the major drinking water contaminant groups: pathogens, organic and inorganic chemicals and disinfectant byproducts (U.S. EPA: 7). Where analytical methods are not sufficiently developed to measure the concentrations of certain contaminants in water, EPA specifies a treatment technique, instead of a maximum contaminant level to protect against these contaminants (ibid.).

3.2.2.1 Physical Treatment

Filtration

The effectiveness of proper disinfection including inactivation of viruses, other conditions being the same, is largely dependent on the freedom from suspended material and organic matter in the water being treated (Salvato: 257).

Particles are removed from water when it passes through a medium of sand, anthracite or another suitable material. Microfiltration and ultrafiltration are types of filtration differing in pore size. They are both promising treatment practices, which are proven to remove protozoan cysts and oocysts (Braghetta et. al: 8), which are likely to resist the disinfectant properties of chlorine. Microfiltration (minimum pore size 0.2µm) has been demonstrated to achieve absolute removal of protozoan species (ibid.). Ultrafiltration achieves absolute removal of protozoa and significant removal of viruses (ibid.). Given the effectiveness of filters it is possible to remove virtually all sediments and larger waterborne pathogens such as giardia and cryptosporidium (Christensen and Parfitt: 21).

Slow sand filters are recommended for smaller systems and sand size should be between 0.25 and 0.35 mm (Salvato: 270). Rapid sand filtration is not suitable for smaller community systems because of the complicated control needed for proper operation. For sand filters to be effective water must be low in suspended solids and have low coliform concentration, and low turbidity otherwise the filter will clog quickly (ibid.). A sediment basin can be utilized to retain water and reduce suspended particles, turbidity and coliforms before filtration.

Disinfection such as chlorination is necessary to kill bacteria which pass through the filter, and that grow or enter into the water distribution system. By filtering out organic particles and other suspended matter from raw water, the introduced disinfectant is less likely to form THMs (ibid.), and will achieve its maximum potential to kill the pathogens.

Coagulation, Flocculation and Sedimentation

During coagulation chemical s are added to the water to destabilize suspended or colloidal solids. Under normal conditions, colloidal material will not settle out, because particles have a negative charge on their surface and repel other particles (Driscoll: 799). Particles therefore remain suspended in solution. By adding coagulants such as aluminum, iron salts and catonic polymers, the negative charge is neutralized and particles will coagulate into larger masses that then settle out (ibid. 800). Optimally under this process, 80 percent of turbidity and bacteria is removed.

UV

Lamps containing mercury vapour are used to generate electromagnetic radiation, which acts as a disinfectant by inactivating pathogens in water passing by (Christensen and Parfitt: 22). The germicidal effects of Ultraviolet irradiation are derived from photochemical damage to the RNA and DNA in the cells of a microorganism, however, the resistance of waterborne microorganisms against UV irradiation depends upon the cellular repair mechanisms available. For some bacterial organisms, the damage to DNA can be repaired through a process called photo-reactivation (Braghetta et al., 1997: 5).

UV radiation can effectively neutralize bacteria, viruses and cysts when properly applied. Recent research has demonstrated that it may also be effective against the more stubborn protozoa such as *Cryptosporidium* and *Giardia* (MOE, 2001: 48). Development of this technology continues, but for now, there are two major drawbacks in its use as a disinfectant – there is no disinfectant residual beyond the point of treatment and any turbidity in the water will interfere significantly with its effectiveness. The ODWS position on this is that “chlorine or other disinfectant must be added after disinfection with UV in order to provide a residual which can be maintained throughout the distribution system” (ibid.).

3.2.2.2 Chemical

Chlorination

In the majority of water systems chlorine is the disinfectant of choice, although current concerns for byproduct formation from chlorination have led to the exploration of alternative methods of chemical disinfection.

Chlorine reacts with (oxidizes) substances present in water such as organic material and inorganic materials. A combination of many factors governs the effectiveness of disinfection including: disinfectant and dose, disinfectant demand of the water, contact time, water pH, temperature, type of micro-organism and concentration of micro-organism (Braghetta et. al. 1997: 1).

In most cases chlorination is the least costly, easiest to apply and often the best method to disinfect public water supplies and control bacterial growth in the distribution system (ibid.). Small amounts of chlorine remaining in the distribution system will serve as a disinfectant from the treatment plant to the tap.

In the United States water treatment relies on detectable chlorine residuals in the distribution system to reduce biological growth, regrowth, to provide protection against local accidental contamination, and to suppress bioloogically related corrosion of materials in the distribution system. (ibid.: 7).

In the second edition of its “Guidelines for Drinking Water” 1993, the World Health Organization stated: “Disinfection is unquestionably the most important step in the treatment of water for public supply. The destruction of microbiological pathogens is essential and almost invariably involves the use of reactive chemical agents such as chlorine, which are not only powerful biocides but also capable of reacting with other water constituents to form new compounds with potentially long-term effects” (World Health Organization, 1993).

Studies indicate that chlorine is relatively ineffective when used for inactivation of *Cryptosporidium* ocysts (Braghetta et. al. 1997: 5). Protozoan cysts are more resistant than bacteria and viruses, therefore chlorine should not be relied upon solely to inactivate them. When water must be continually disinfected due to the possibility of contamination or the presence of cysts, water treatment should incorporate filtration and disinfection. When used with filtration techniques, chlorine is an effective disinfectant against virtually all infective agents such as bacteria, viruses and protozoa (Health Canada, 1999).

When chlorine comes into contact with organic sediment in water, it can bind to and form carcinogenic byproducts known as trihalomethanes (THMs). In 1999, Health Canada reported that THMs are linked to increased bladder and colon cancer in long time drinkers of chlorinated water (Christensen and Parfitt: 10). Adverse pregnancy outcomes including miscarriages, birth defects and low birth weights are also associated with THMs at high levels of exposure (ibid.) Filtration can be employed to remove THM precursors. However Health Canada’s standpoint on the debate at this point is that “current evidence indicates that the benefits of chlorinating drinking water - reduced incidence of waterborne diseases - are much greater than the risks of health effects from THMs” (Health Canada, 1999).

In Ontario the DWPR states that no water will be allowed to enter a distribution system or plumbing unless it has been chlorinated or equivalent (except in cases where a variance is sought) (MOE, 2000). For now, the requirement to chlorinate in all cases seems to be the wisest one. The wording of the regulation allows for exemptions and alternatives, but a stringent set of circumstances must be applied in granting such approvals. The standard for granting variances must in all cases be the effective prevention of water borne disease.

Chlorine dioxide

An example of a possible alternative to elemental chlorine for disinfection is chlorine dioxide, which has several advantages over chlorine. It is considered to be effective in killing ‘encysted’ parasites such as cryptosporidium and it does not react with particles to form THMs (Christensen and Parfitt, 2001: 21). It is also more effective than chlorine at a pH of greater than 7 (Driscoll, 1995: 813).

However the disadvantages outweigh the advantages. Chlorine dioxide is several times more expensive than chlorine and it cannot be transported due to its explosive nature and therefore must be manufactured on-site. It forms chlorate and chlorite compounds whose toxicity has not yet been fully determined and to determine the full extent of chlorine dioxide’s adverse health effects more research is needed (Christensen and Parfitt: 21). This serves to illustrate that there are more effective methods than the standard of chlorine, but factors such as safety and cost must be weighed against the intended benefits.

Ozone

Ozone is an unstable form of oxygen, which can be generated from air or oxygen and bubbled through the water acting as a disinfectant. It is also a strong oxidant and powerful germicidal agent, which is effective in killing bacteria and viruses including giardia and cryptosporidium (Christensen and Parfitt, 2001: 22). Ozone requires a short contact time with water and is effective over a wide pH and temperature range in contrast with chlorine (Salvato, 1982: 294).

Ozone is however not a practical disinfectant in water systems because, like UV light, it is not an active disinfectant residual in the distribution system due to the fact that it oxidizes quickly after use (7-8 minutes), therefore chlorine would need to be added for disinfection in the distribution system. Ozone is also more expensive than chlorine. It is toxic and cannot be stored as a compressed gas so must be generated on-site (ibid.). A side effect of ozone is it produces assimilable organic carbon, which promotes bacterial growth.

3.2.3 Other Operating Criteria

Successful and responsible operation of a waterworks plant involves many aspects. In addition to treatment criteria there are other operating guidelines which are necessary to ensure that existing procedures are followed. The employees performing plant function need to be capable individuals with knowledge of relevant policies and procedures and the reasons for them for waterworks to operate correctly.

3.2.3.1 Staff Training

The delivery of a safe water supply will depend in large part on the skills of the technicians responsible for it. Water treatment plant staff should be fully certified and certification standards need to be province wide. Different requirements for certification may depend on the types of procedures employed in a given plant. Larger waterworks using methods such as coagulation/flocculation in addition to chlorination and filtration would require technicians certified for the operation of coagulation/flocculation processes. It is not necessary for operators of smaller waterworks to have training in treatment methods not utilized at their plant.

Staff must be certified in every level and stage of treatment in use at their place of employment. Every year or two a specified number of hours of training should be required to keep operators updated on new research, technologies and existing expertise. In the case of existing employees they will need to be required to complete training for certification in order to maintain their current positions.

Ontario now requires the use of certified operators however some have been exempted from training and certification requirements having been employed before they existed (Christensen and Parfitt, 2001: 32).

In the United States individual states must develop compulsory training and certification programs and can only employ trained and certified operators in order to qualify for certain infrastructure grants (ibid.: 35). Certification must cover every phase of treatment at every size operation from small to multi-million gallon treatment plants.

3.2.3.2 Written Policies and Procedures

The Ontario DWPR provides a basic standard set of requirements. It is the responsibility of the waterworks to ensure that the means are in place, based on local conditions, to meet these requirements. Detailed procedures for equipment operation, testing protocols, treatment methods, maintenance schedules, record keeping, contact lists and reporting chains and any other aspect of the operation must be written and read. These must be available for inspection by regulatory agencies to evaluate the effectiveness of health hazard control methods. They must also be updated as often as necessary to ensure that the best practices are being employed.
useful appendices to the document would of course include any relevant statutes, copies of employee certifications, and background information on the health hazards that the operation is set up to eliminate.

3.3 Monitoring Criteria

Without monitoring, no one can know whether or not its water poses a health risk to consumers. Sampling and analysis of water in the distribution system is an essential safeguard of water safety, as it is the only way to detect substances that may cause adverse health effects in the absence of any changes in taste, odour or appearance of the water.

A complete monitoring protocol will include types, locations and frequency of samples to be taken, based on the source of the water, treatment methods and population served. It is essential that the monitoring process be properly carried out to satisfy its purpose. For this reason, detailed sampling and analysis requirements have been set out in the DWPR. Prior to this, testing was carried out under the non-binding protocols of the Ontario Drinking Water Objectives. To ensure accurate results and their proper reporting, laboratories performing these analyses must now be accredited (O. Regulation 459/00, s. 7(3)).

The process of accreditation includes mandatory performance testing where the laboratory provides results for audit samples to demonstrate the accuracy of its methods and an on-site assessment, which is repeated every two years (Christensen and Parfitt, 2001: 29). Accreditation is granted by the Standards Council of Canada (SCC) upon the recommendation of the Canadian Association of Environmental Analytical Laboratories (CAEAL) (ibid.).

Testing must address immediate and long-term health risks as well aesthetic parameters. Because there are so many substances listed in the standards, each requiring specific, often costly lab tests, frequent testing for all of them by small community water works would neither be practical nor affordable. The protocol should thus focus on contaminants identified during land use assessments.

3.3.1 Sources of Standards

The Ontario Drinking Water Objectives for many years set the maximum limits for over 80 contaminants that have known or suspected adverse health effects in sufficient concentration. These are referred to as Maximum Acceptable Concentrations (MAC), the surpassing of which was intended to trigger reporting and corrective actions. Where there was not sufficient toxicological data to establish a MAC with reasonable certainty or not practical to establish a MAC at the desirable level, an Interim Maximum Acceptable Concentration (IMAC) would be established. These were also triggers for reporting and corrective action. All of this is still the case, but the Objectives, since being adopted by reference in new legislation, are now Standards, which means that corrective actions and reporting are now mandatory.

The Drinking Water Protection Regulation (DWPR), made under the Ontario Water Resources Act came into effect August 26, 2000, and will be fully implemented by January 2002. Limits for contaminants set out in the Ontario Drinking Water Objectives are now given the force of law under the Regulation, which also includes schedules of sampling and analysis for their detection. In them, specific monitoring procedures are set out for microbiological parameters, chlorine residuals, turbidity, volatile organics, inorganics and sodium, fluoride, nitrates and pesticides. Frequency and location of sampling depends on water source, category of contaminant, treatment methods and population served. Requirements over and above these may be set out as conditions of approvals, orders or directions issued by the MOE on a case-by-case basis.

It is worth noting that the ODWS is one of a number of similar lists that serve the same purpose. The Guidelines for Canadian Drinking Water Quality, which are not legally binding, also set limits on potentially harmful microbiological, chemical and radiological contaminants. In many cases, the MAC's are different. The Safe Drinking Water Act in the United States lists a number of compounds not found in its Canadian counterpart, and has much stricter limits on many that are (Christensen and Parfitt, 2001: 5).

The problem that arises here is that the standards are published based on toxicology studies that estimate adverse-effect levels of identified contaminants. If different sources are presenting different results for the relative toxicity of a given contaminant, questions will certainly be raised about which source is most correct. Irrespective of the fact that safety factors are built in to ensure that MAC's are 10 to 10, 000 times lower than exposure levels at which adverse effects are observed (Health Canada, 1997: 2), consistency in the standards will increase confidence in them. For the sake of credibility, definitive standards should exist, at least within Canada. Conflicting information coming from federal and provincial authorities will necessarily call the standards themselves into question.

3.3.2 Microbiological Standards

A number of diseases can be transmitted by drinking water by a number of infectious agents (or pathogens). Among these are the bacterial agents that cause Cholera (*Vibrio cholerae*) and typhoid fever (*Salmonella typhi spp.*) and gastro-intestinal illnesses (*E.coli* O157:H:7; *Campylobacter)*. Pathogenic protozoa (*Giardia intestinalis; Cryptosporidium*) and viruses (Hepatitis A) can also infect a host via drinking water. Testing for each of these requires a specific detection procedure, which can be costly and time consuming. Additionally, some of these infectious agents cause disease at concentrations low enough to make such detection exceedingly difficult. As most of the pathogens of concern are residents of the gastro-intestinal tract of warm-blooded animals, a general test for indicator organisms that also reside there is used.

Coliforms are a group of microbes (fecal coliforms, total coliforms and enterococci) that serve as useful indicators of fecal contamination as they are plentiful, easy to detect by a simple and inexpensive test, and hardier outside of their hosts than the pathogens. Coliforms have thus become universal indicators of the contamination of water by sewage, and therefore the possible presence of pathogens. If coliform organisms are contained in a water sample in numbers that indicate that the supply might be unsafe, water should be chlorinated or boiled - processes that destroy most microbial pathogens – before consumption.

According to Ontario's new Drinking Water Protection Regulation, if E. coli, fecal coliforms or total coliforms are detected in any sample other than a raw water sample it is an indicator of adverse water quality. The presence of Escherichia coli, one species in the fecal coliform group, is a definite indicator of the presence of feces (Christensen and Parfitt: 8). Also considered an indicator of adverse water quality is the presence of more than 500 colonies per ml on a heterotrophic plate count. A high general load of bacteria is a good indication that simple barrier or disinfection methods of excluding them from the water supply have failed. Once any of these is detected, resampling and treatment protocols are implemented.

Microbial water testing should be analyzed as soon as possible once a sample is taken. Bacteria are unpredictable due to factors such as time, temperature, and nutrient supply which can all affect survival and growth of bacteria. Bacteria density can change substantially over time. Samples should be put on ice and tested within 6 hours to prevent changes in total coliform counts or bacterial densities (Stewart: 85). At temperatures above 55 degrees Fahrenheit nutrients could cause an elevation in bacteria levels (ibid.). On the other hand if the sample is stored too long the bacteria could exhaust its food supply and die off. Prompt delivery is critical, so a nearby or on-site laboratory is recommended to ensure that test results reflect the true condition of the submitted sample.

3.3.3 Other Standards

In most small rural systems the threat of industrial chemicals is minimal. In the event of the presence of industry with the potential to pollute source water, water plants may need to alter their monitoring procedures to account for any possible contaminants associated with the industry at issue. Otherwise agricultural chemicals, nitrates and chlorine residuals are the next areas of concern following microbiological contaminants.

In agricultural communities thousands of herbicides, pesticides and fertilizers are used regularly. Some of these are carcinogenic or are associated with adverse health effects (Christensen and Parfitt: 11). To ensure human health is protected it is necessary to test for all compounds found in agricultural chemicals sold in Canada. It is also a good idea for MACs to be far below levels at which adverse health effects have been detected, as is the case with the Canadian drinking water guidelines. The Guidelines also recommend more frequent sampling of water supplies with probability of contamination, to ensure suspected substances remain below the acceptable limits (ibid.: 12). Other suggestions include the sampling of water in correspondence with seasonal application in areas where pesticides and other chemicals are applied seasonally (ibid.). Contaminants will need to be added or levels modified when new research and information becomes available to suggest changes and additions would be beneficial to human health.

The new DWPR in Ontario lists 84 new, revised or reaffirmed drinking water standards. It puts in effect binding sampling and analysis requirements for microbiological parameters, turbidity, volatile organics, inorganic chemicals, nitrates, pesticides, and chlorine residuals. The frequency depends on the source of the water, population served, and treatment methods employed (O. Reg. 459/00, Schedule 2).

The new DWPR lists trihalomethanes (described above), as a volatile organic compound required to be monitored. Any system using chlorination for disinfection must therefore test for THM's. In 1993 an IMAC of 0.1 milligrams per litre was established for THMs, based on the cancer risk associated with chloroform, the THM most often present and in the greatest concentration in drinking water. An evaluation of the available studies at that time estimated that the cancer risk from drinking water meeting the guideline over a lifetime was essentially negligible, and that the reduction of water-borne illness by chlorinating water far outweighs the risk of adverse health effects from THM's. (Health Canada: 1999, 4). High levels of THM's may however be useful indicators of the need for additional filtration to remove the organic compounds necessary for their formation. Due to the general lack of turbidity in groundwater, this should not be a regular occurrence.

In addition to the maximum limits set for hazardous substances, monitoring criteria must be established for the treatments meant to reduce them. To reduce the risk to human health from distribution system contamination, a minimum chlorine residual level must be present throughout the system. Monitoring this will require sampling points throughout the distribution network. Inadequate chlorine residual allows the potential for regrowth of pathogens in the distribution system and should be taken seriously. The new DWPR identifies residual levels below 0.5 mg/L as an indicator of adverse water quality, requiring immediate correction and consultation with the local MOH (O.Reg 459/00, Sch. 6).

3.3.4 Testing Requirements

The basic objective of drinking water monitoring is to ensure that drinking water is potable and aesthetically acceptable. A proper testing protocol will assess compliance with the ODWS and with any terms and conditions set out in Certificates of Approval. Consistent application and recording will allow the identification of trends and changes in water quality, providing early warnings of those that might be detrimental. Specific requirements for monitoring a wide range of standards are set out in the ODWS and are legally enforceable under the DWPR.

In Ontario under the OWRA, every municipal water system must obtain a certificate of approval from the Ministry of the Environment for establishment, alteration, extension or replacement (R.S.O. 1990, c. O.40, s. 52) and must submit an engineer's report under the DWPR (O. Reg. 459/00, s.13). The operator of the system may also be required to submit other information, including plans, specifications, and to carry out and report on tests or experiments relating to the water supply or the work to be undertaken (R.S.O. 1990, c. O.40, s. 52). Upon reviewing this and other information, approval may be granted, and terms and conditions may be attached.

The engineers' report will include assessments of operational procedures and physical works and recommendations, as well as recommendations for a monitoring regime for the whole waterworks, including the distribution system, to ensure compliance with the DWPR. Once reports are reviewed, a new consolidated certificate of approval can be issued which may include a set of site-specific terms and conditions that are binding on the waterworks owner. It is here that any additional sampling requirements may be identified, compliance with which is prescribed by section 7(b) of the DWPR. This process will allow a case-by-case tailoring of a monitoring protocol, whose baseline will be the general parameters outlined above and specified in Schedule 2 of the regulation.

In order to ensure that monitoring serves its purpose, it must be properly carried out. The use of sterilized containers, locations representing the delivery system as a whole, proper storage during transport and time between sampling and analysis are all important considerations to ensure that test results accurately reflect the characteristics of the water at the time of sampling. Bacteriological counts for example can change rapidly if time and temperatures are not properly controlled. Additionally, improper sample handling can result in post-collection contamination unrepresentative of the sample's source. A regulating agency such as the MOE should have responsibility for specifying appropriate sampling procedures and methods, and for approving sampling locations and maintenance requirements for the plant and the distribution system. Training of operators as well as environmental officers charged with verification duties must be available.

On August 8, 2000, the Minister of the Environment announced the intention to require all operators to undergo an additional 36 hours of ministry approved training over three years to ensure they have the most current knowledge, skills and experience needed to sample water quality. In addition, a new license will be created for water quality analysts. This license will be required to perform a range of tests for operational parameters (MOE, 2000). Finally, the mandatory accreditation of analytical laboratories under the DWPR should add extra confidence in results from analyses that require their services. In the long run, conscientious application and verification of the monitoring protocol (frequent and documented sampling of raw, treated and distributed water) will increase public confidence in its drinking water.

The pathway between source water and the end user's tap can be a long one. While a sample of water taken just before it exits the plant may conform to the standards, that is not a guarantee that this will be the case when it exits the tap. Monitoring protocols should be extended to the distribution network to provide for early warning of any problems that may manifest themselves after the water has left the plant. Remote sampling stations will provide more accurate representation of water that is actually consumed, by measuring the changes that occur over time and distance (e.g. chlorine residuals, leached metals, THM's). They may also indicate breaches in the network that may be allowing pollution to enter the system between treatment and consumption.

In addition to monitoring water quality parameters, there must be procedures in place to ensure that distribution system materials and equipment are in good repair at all times. Given the potential for contamination to spread quickly throughout a distribution network, thorough inspections of the hardware itself are essential. Installation, testing and repair schedules for piping, water storage facilities and pumps are all part of the effective oversight and management of the operation of the system and the delivery of safe water.

3.3.5 Staff Training

System operators, technicians and analysts play a critical role in the reliable delivery of drinking water. Effective oversight and management of the water-delivery process requires expertise on maintenance requirements, knowledge of standards and the reasons for them, and overall competency with interpreting observations on system performance. Mandatory training and certification requirements will ensure that this expertise is always at hand.

Classification of training and licensing of staff will depend on job duties and responsibilities. As has been noted above, water testing is not as simple as turning on a tap and filling a jar. Close attention must be paid to how a sample is prepared, stored and transported, how it is analysed, and how results are recorded and communicated. Staff collecting samples must be trained in these procedures as well as in the interpretation of results and the conditions that might have led to them. Complete training will also include familiarity with corrective actions and reporting procedures that are triggered by certain results. Written copies of these must be readily available to the staff regardless.

Ontario regulation 435/93, Water Works and Sewage Works sets out detailed requirements for the licensing of operators in four classes depending on the size and complexity of the system. All plant operators are required to undergo 40 hours of training each year in courses such as new or revised operating procedures, refresher courses in existing procedures, safety training and other related courses that improve operator knowledge and skills. It is the responsibility of facility owners to ensure training requirements are met. The MOE is currently considering an additional mandatory training course for water sampling (outlined above). This is an encouraging step, which would provide and excellent opportunity to educate water works owners and operators on the correlation between the ODWS and human health. This type of knowledge will contribute to a greater understanding of the rationale behind monitoring, corrective actions and reporting.

3.4 Contingency Plans

There must be a written and periodically reviewed contingency plan to ensure that an uninterrupted supply of potable water is available. Should maintenance be required or should any malfunctions occur, provisions should be made for access to an alternative supply or for additional precautions.

When a water plant has to shut down it is a very public event requiring extensive communication. Public health units, fire departments and consumers need to be informed and given advice on quantity and quality of remaining reserves (Dart 1993: 353). Advice will need to come from government agencies and experts familiar with the facilities.

Continued sampling and testing is essential. Expert advice at all stages is important. Some contaminants should not even be allowed entry into the plant due to the fact that they are not treatable or they may be corrosive to facility materials. Others, however, may be treatable enabling the plant with a few minor treatment changes to return to service swiftly (ibid.). To handle problems quickly and professionally, a list of experts should be developed, particularly within regulatory agencies, to contact when problems arise.

When exceedances of health-related parameters are detected the first step should always be resampling for verification to avoid misleading expenditures for what could have been misleading results. A reserve supply of water should be available until results are obtained. An active response is not practical until analytical error is ruled out (ibid.: 352). As data becomes increasingly validated, contact with necessary agencies will be needed. Local health departments must be consulted in the event of an emergency situation, as they are required to have written protocols for dealing with adverse water quality reports and are positioned to issue advisories to the community.

In partnership with the local water provider, health departments must act quickly and in unison to bring the problem under control. Responses will depend on the type of report received. Flushing, chlorinating and finding an alternate water supply are all possible actions. When the contamination is microbiological the response is chlorinating and flushing the mains. Measuring the chlorine residual in the distribution system may help to determine the severity of the situation and the appropriate action. Decisions must be made in direct consultation with the Commissioner of planning and public works and the Minister of Health if warranted. The MOH is ultimately responsible for approving decisions related to emergency treatment, supply use restrictions and public notification (Halton Regional Health Department, 2000: 6). If necessary and appropriate, the MOH can issue a Boil Water Advisory. The success of this partnership depends on clear and documented procedures.

Ontario is not required by law to develop plans to deal with emergencies (Christensen and Parfitt: 34). The DWPR does however require extensive reporting responsibilities, placing Ontario ahead of other Canadian provinces and territories in this area. The owner of a waterworks is required to immediately notify the Medical Officer of Health and the Ministry of the Environment if a parameter exceeds its MAC or IMAC or if there is an indicator of adverse water quality (MOE, 2000). Results must also be reported to the environment minister at standard intervals and in the incidence of contamination. Labs performing water analysis are required to notify the Medical Officer of Health, Minister of the Environment and the water works owner if a lab test exceeds a standard or indicates adverse drinking water quality (ibid.). Reporting must be made to a live person and both the laboratory and the waterworks owner must report in writing to the MOH and the MOE within 24 hours.

In the event of adverse water quality corrective action must be taken and the water works owner must provide confirmation of this. Corrective action may include: re-sampling, increasing the dosage of chlorine, and flushing the watermains (ibid.). Direction may be given from the Medical Officer of Health and the Ministry of the Environment.

The Drinking Water Protection Regulation prescribes corrective actions for adverse water quality as indicated by fecal coliforms, total coliforms, unchlorinated water, high plate counts, high sodium counts and certain pesticides. In each case, resampling and consultation with the MOH are required (O.Reg 459/00, Schedule 6). Additionally, the waterworks owner is required to post a public notice when drinking water has not been tested or corrective action specified in the regulation has not been taken. Notices must be posted in a prominent location where it is likely to be seen by consumers (ibid. s.10).

A written plan for notification of the public detailing locations where notifications are to be posted and possible media use procedures is recommended. Also recommended is an approval process whereby the plan is reviewed and approved or changes required by an outside agency such as the MOE or local MOH.

3.5 Verification System

As with the regulation of land activities discussed above, the regulation of water delivery systems enables a verification system based on routine inspections, investigations, enforcement and clear reporting strategies. In addition to these, a public disclosure framework is built in, which ensures that records of processes are available for public viewing. Together, these can be useful assurances that water works staff is carrying out their duties diligently, and that public confidence in the water supply is maintained.

The DWPR has removed much of the discretion previously allowed water works operators by requiring public information and strengthening communications among laboratories, the medical officer of health and the MOE. Section 11 requires waterworks owners to disclose all water test results, approvals, current orders or directions, copies of the ODWS, copies of the regulation and quarterly reports to any member of the public who requests it.

The quarterly reports, submitted to the Director under the regulation, describe plant operations and the quality of drinking water as determined by the testing protocol. This satisfies both regulatory verification and public accountability, as they are for both public and official audiences. To strengthen this further, owners must take “effective steps” to advise users of the system of the report’s availability. This might be as simple as including a summary of the report with water bill mailouts, with information on how to obtain the full document. The new regulation also requires waterworks serving over 10,000 people to post results on a Web site on the Internet (O.Reg 459/00 s. 11).

The waterworks plant and the distribution systems are governed by regulations and standards which are legally binding and provide a measure of assurance that water reaching the consumer is safe to drink. In Ontario the quality assurance system for waterworks has improved considerably under the new DWPR. It is necessary however to verify that the system is appropriate, that all monitoring criteria are carried out, and that full compliance with regulations is being achieved.

Most legislation enables a verification function based on enforcement and/or abatement, and the OWRA is no exception. Section 5 states:

> “The Minister shall appoint in writing such employees of the Ministry or, subject to the approval of the Lieutenant Governor in Council, such other persons as the Minister considers necessary as Directors in respect of such sections of this Act and in respect of such regulations or sections thereof as are set out in the appointments (R.S.O. 1990, c. O. 40, s. 5 (1)

And further,

> “The Minister or the Agency, as the case may be, may designate in writing one or more of its officers or employees as provincial officers or inspectors for the purposes of this Act and the regulations.” 1993, c. 23, s. 73 (5).

And further,

> “The Ministry shall maintain a record of orders, approvals, requirements, directions and reports issued under this Act.” R.S.O. 1990, c. O.40, s. 13 (2).

These are all functions written into the Act that enable the Ministry of the Environment (or the Ontario Clean Water Agency) to verify compliance with all processes that are designed to ensure the safe delivery of potable water. Periodic inspections will serve to evaluate these processes, examine procedures and identify any deficiencies. They also serve as an opportunity to educate owners and operators on new developments and to ensure that current practices in the plant correspond with current knowledge about the delivery of the safest water possible.

These periodic inspections of the waterworks could be part of a comprehensive sanitary survey, similar to that described in the United States Environmental Protection Agency’s Proposed Ground Water Rule (USEPA, 2000: 30219). It is an eight-part review of the adequacy of the groundwater system that includes examination and evaluation of the following eight components:

1) Source – quality, quantity and potential for contamination from land uses
2) Treatment – handling, application and storage of chemicals, records

3) Distribution System – hardware, system integrity
4) Finished Water Storage – as above
5) Pumps – appropriate design and maintenance
6) Monitoring and Reporting Data – effectiveness of source protection, treatment and other quality issues
7) Water System Management and Operations – general review of management practices, adequate resources and system upkeep
8) Statutory Compliance – regulations, orders, directions.

By empowering these same officials with enforcement duties, an additional incentive is in place to ensure that the owners are carrying out treatment, monitoring, maintenance and reporting duties properly. By empowering officers to investigate potential impairments to water, to examine relevant records, conduct tests and to require the production of any relevant information, the basis is laid for a periodic and detailed evaluation of the water works (ibid. s. 15 (2)). During this evaluation, deficiencies can be identified and corrections can be ordered, with the understanding that failure to do so will result in penalties under the Act.

The verification system has been further strengthened by the reporting requirements set out in the new regulation. Any exceedance of MAC's or IMAC's or other indicators of adverse water quality must be reported by the owner of the treatment facility as well as by accredited labs to the Ministry of the Environment and to the local medical officer of health. Notice must be given verbally to a live person immediately, followed by written notice within 24 hours (O. Reg. 459/00, s. 8). This amounts to an effective surveillance system that should lead to timely identification and correction of water quality problems through the efforts of health and environment authorities, and owners and operators of treatment facilities.

The new requirement for laboratory accreditation is also an important enhancement of the verification process. Laboratories that are accreditated are listed with the MOE and the Standards Council of Canada. The MOE maintains a database of all the labs providing drinking water analysis with a list of all parameters for which each lab is accredited. Inspections of laboratories are carried out to ensure that they maintain their documented quality system for which approval was granted. An on-site assessment is repeated every two years and labs are required to provide evidence of certification and proficiency of the analysts performing tests. Labs not maintaining a proper quality system can have accreditation automatically withdrawn for that particular test procedure. It is recommended that waterworks using the lab should be informed of its removal. Waterworks are required to identify to the ministry the laboratories used for drinking water testing and the parameters tested by each . Waterworks are also required to inform the ministry three business days prior of any change in the laboratories they use.

4.0 END USER

The primary purpose of the assessments, safeguards and contingency plans referred to in the preceding sections is to ensure that the water that reaches its consumer is of acceptable quality and is safe to drink. The process that starts with source water and ends at the tap involves many protective measures, whose success depends on different types of expertise. The responsibilities for ensuring the protection and maintenance of drinking water thus lie with different agencies. Hydrogeological assessments, inspections of manure storage facilities, examination of utility records and water testing are all important components in ensuring water quality but they are unlikely to be carried out by a single regulatory body. Ministries of the Environment, Natural Resources and Agriculture Farms and Rural Affairs and municipalities all have important roles to play in the protection of drinking water. The protection of the health of the end user however falls squarely within the purview of the public health system. This should not be interpreted as a general duty of health units to oversee the operation of water systems, but rather to protect the community from health hazards that may appear within them. The public health system (medical officers, boards of health, public health unit staff) thus constitutes the final barrier in the process.

This system comprises the local boards of health that are responsible for community health protection in each of Ontario's 37 health units. Their authority for this responsibility originates mainly in the Health Protection and Promotion Act, which also sets out the types of activities required of the boards, the medical officers of health, and their staff for that purpose. As an adjunct to the Act, the Minister of Health and Long Term Care publishes the Mandatory Health Programs and Services Guidelines (MHPSG) for the form these activities are to take. Among these is ensuring that community drinking water systems meet health-related standards as published in the ODWS, with a view to reducing the incidence of water-borne illness in the population (MOHLTC, 1997:43).

The Safe Water program under the MHPSG includes requirements of local boards of health to maintain lists of all drinking water systems, receive and respond to adverse water quality test results, interpret water analysis reports, and to provide information about health related parameters and their potential effects. With these duties, the local board of health, through its health department staff, has a broad responsibility to monitor water quality and respond immediately in accordance with the ODWS to protect the health of the public when it fails to meet the accepted standards. Because health department responses may be initiated by reports from agencies within the water-delivery process or from members of the community, public health mechanisms are valuable components in monitoring the quality of the system as a whole. Written protocols are in place to protect consumers from drinking water quality problems regardless of where they appear in the process.

4.1 Community Health Protection

In order to ensure that public demands regarding safe water are met, it is essential that health departments be equipped to meet their legal responsibility to investigate health hazard reports and to act immediately to protect the health of the public whenever the report is justified. This is a general duty of the MHPSG that applies to all programs within it. Included in this program are requirements for the provision of timely and essential information to the community and monitoring health hazard management strategies. The purpose of these requirements is to identify health hazards, take appropriate action in order to ensure community health protection and continued public health services delivery in the event of a health hazard (ibid.)

4.1.1 Surveillance

In an ideal situation, any threats to drinking water quality and human health have been identified, reported and eliminated before the water reaches the tap of the consumer. In other words, any health-hazard controls that are implemented at the point-of-use should, if anything, be a part of a contingency plan and not of the permanent process. If all of the monitoring procedures are being properly followed, any deviation from accepted parameters within the water delivery system should be quickly identified and reported to the medical officer of health for action, as required by Section 8 of Ontario Regulation 459/00. In maintaining a file of such reports, the health department has at its disposal a vital tool for the ongoing risk assessment of a given water delivery system. A historical record of reports, complaints and inspection results allows for the identification of certain patterns and of the types of hazards that may be characteristic of that system. The current recommendation for retention of these types of records is two years plus the current on site, and an additional four years off site (alPHa, 2000, adapted from the Region of Peel Records Retention By-law). This set of records should complement those now required by Ontario Regulation 459/00 - owners of water treatment and distribution systems must maintain prescribed records for a period of at least five years (O.Reg. 459/00, s. 14), which must be made available for examination upon request by any member of the public (ibid. s. 11)

In order to satisfy requirements of the Mandatory Health Programs and Services Guidelines Safe Water program, boards of health must maintain an ongoing list of all drinking water systems that fall under the OWRA (requirement 1a) and receive all reports of adverse drinking water test results from the listed systems (requirement 1b). Upon receipt of such a report, board of health staff can quickly initiate appropriate action to reduce adverse health outcomes resulting from exposure to health hazards. Action on an adverse water quality report may take on different forms, as allowed by the broad provisions of Section 13 of the HPPA, which states

> "A medical officer of health or a public health inspector, in the circumstances mentioned in subsection (2), by a written order may require a person to take or refrain from takingany action that is specified in the order in respect of a health hazard." R.S.O.1990, c. H. 7, s. 13.

where subsection (2) requires an opinion, upon reasonable and probable grounds that a health hazard exists, and that the contents of the order are necessary to decrease or eliminate the risk to health. It is a general provision for the protection of health that can be applied to a host of different situations. With all of the health-related safeguards already in place in the drinking water delivery process, this should be a last resort. It needn't be employed where other statutes have specific clauses to ensure these safeguards.

A close reading of the requirements and standards under the MHPSG Safe Water program shows that the public health role is a passive one. Ensuring safe water requires consideration of many factors, including the stability of the source, the nature of the treatment and distribution system, the expertise of its operator and the nature of its monitoring system. These are governed by the MOE, and as such subject to its oversight. The role of the health unit is not to actively ensure that the delivery system is meeting all of its requirements, but rather to warn the community if there is some immediate threat health.

Local health departments do actively monitor water quality in some cases, during routine inspections of certain facilities. Point-of-use water samples may be taken during the course of inspections of restaurants, hospitals, day cares and long term care facilities. The main purpose of this is to identify potential localized problems in high-risk facilities (i.e. facilities that serve large numbers of people or house populations that are more likely to suffer adverse health effects due to weakened immune systems). This limited point-of-use monitoring strategy may serve to identify system-wide problems, but these routine inspections are infrequent and systemic problems are far more likely to be brought to the attention of the health unit as a result of proper monitoring farther upstream. The impracticality of a routine, universal and comprehensive point-of-use monitoring strategy is obvious. Health departments must thus rely on the proper monitoring of the distribution system by its operator, and to a lesser extent, on the end user who might report a suspicion of problems with water quality.

As well, health units are responsible for the investigation of and appropriate response to communicable disease outbreaks, in order to determine causes and management strategies (MOHLTC, 1997: 36). The board of health is required by the Guidelines to provide an initial response or investigation when occurrences of a disease or mortality appears to be significantly higher than expected. This function relies on the efficiency of the reporting system that is set up to ensure that incidence of disease is monitored. The pathogens that are associated most often with water-borne illness are all classified as reportable diseases. If a physician, laboratory, director of an institution (among others) is of reasonable opinion that a person is infected by or is suffering from a reportable disease, he or she is required by the HPPA to report the possibility to the medical officer of health (R.S.O. 1990, c.H.7, ss. 26-29). Once such a report is received, the matter is investigated and appropriate action taken, as required by the Mandatory Health Programs and Services Guidelines.

This is also based on a passive role in receiving reports from the community (e.g. health care workers, school staff, laboratories). Upon the receipt of a series of such reports, patterns may be identified, which may indicate further areas of investigation. The receipt of several reports of a disease with the same symptoms and onset might indicate an outbreak. If the cases seem to be temporally and spatially unrelated, it might indicate a common source, such as water. The next step might be to inquire at the water utility about any problems they might be having. It would be reasonable to expect that such an inquiry would result in reliable information based on the qualified operator’s expert evaluation of how the system is performing at that time. By the same token, the requirement of the MHPSG for boards of health to ensure that drinking water meets required standards should be considered met with such an inquiry. Now that reporting requirements have been tightened by the DWPR, information on water quality problems should generally be in the hands of the public health department before this type of inquiry would need to be made. This ensures that management of the situation begins as quickly as possible after qualified water systems operators identify potential problems and report them to the medical officer of health.

The public health system also has a built-in reliance on the individuals it is set up to protect in that there are specific rules about responding to public concerns. If the process of monitoring water quality from source to tap is taken as a whole, the end user becomes part of it as the final judge of its acceptability. While the end user may not have the necessary expertise to make judgements about the safety of the water, health department staff has direct access to those who do. It thus serves the system well when the end user is aware of his or her recourse to the public health system through the local health department if he or she has concerns about the water coming from the tap

Timely response to such reports (regardless of their origin) is required of the board of health by the Mandatory Health Programs and Services Guidelines. Under Health Hazard Investigation requirements, boards of health must provide 24-hour availability of staff, same day assessment and initiation of action within 24 hours of confirmation of a health hazard (MOHLTC, 1997: 7).

4.1.2 Public Information

The primary role of boards of health is to protect and promote the health of the population (MOHLTC, 1997:1). The prescribed duties of boards of health are many, but all of them are means to that end, with a primary focus on primary prevention – eliminating the underlying causes of ill health.

From a public health perspective, the control of health hazards begins before they have the opportunity to cause adverse effects. This can be accomplished in different ways according to circumstance, but raising awareness is always essential. Requirement 5 of the Health Hazard Investigation program states that the Board of Health shall provide educational materials to raise public awareness of health hazards.

Information on various public health issues related to drinking water is made available to the public by any health department, including:

- Descriptions of pathogens transmitted through drinking water and their health effects
- Point-of-use treatment devices
- Maintenance and disinfection of wells
- Summaries of the published standards for drinking water contaminants
- Instructions for submitting water samples for testing
- Roles and responsibilities of government agencies in drinking water protection.
- Fact sheets on recent research on various water quality issues

It is worth noting here that the target audience for much of this information is the owner of a self-contained water supply system that is not subject to the same kinds of quality assurance measures being addressed in this paper. The information thus provides the private well owner with the knowledge required to ensure the safety of drinking water for which he or she has primary responsibility.

It is also worth noting here that Ontario has taken an important step in making the water works answerable for their actions and educating the public on the quality of the water they are receiving. The DWPR now requires the preparation of right-to-know reports and is the only jurisdiction in Canada to do so. Copies of water analysis results, approvals and orders, and quarterly reports on water system performance and compliance are now specifically required to be made available for public examination at no charge (O. Reg. 459/00, s. 11).

It is not a legislated requirement, but local health departments will often build in point-of-use water testing protocols. Samples may be taken on a routine basis from what are considered high-risk places – places where the effects of health hazards might be amplified due to weaker immune systems, close-quartered populations or a heavy user-load. Examples of these include day cares, long term care facilities and hospital kitchens. This is an example of a proactive risk-based monitoring service that at least puts an extra safeguard in place where a local problem could have a significant deleterious effect to the health of the end-user.

4.2 Health Protection and Disease Prevention

While the focus of public health is on primary prevention, situations may arise that require a reactive response. While boards of health do not monitor the operations of a water delivery system, it does have the responsibility to protect the health of the community if it receives reports of problems from those who do. This adds an extra element to contingency planning by protecting the community from these problems for as long as it takes for operators to remedy them.

The requirements and standards under the Safe Water program in the MHPSG obligate boards of health to have

a) a written protocol for dealing with adverse drinking water test results from the systems for which they maintain list and,
b) act immediately in accordance with the ODWS to protect the health of the public whenever adverse drinking water tests are received.

The written protocol will need to address the details of several possible responses. In some cases, it will suffice to monitor the corrective actions of the owner of the water works. In others, actions may include superchlorination or flushing orders in conjunction with immediate public notification to boil water or seek alternate sources. In either case (as with the range in between) the health department must act quickly, in conjunction with other responsible agencies, to enact measures to protect community health when sample results indicate potentially unsafe drinking water. The success of this corrective action will depend on a detailed and clear response protocol, that itemizes in detail the steps that are to be taken and by whom.

This contingency plan as a whole may be modeled on the general emergency plans that municipalities are empowered (or required in some jurisdictions) to develop by the Emergency Plans Act of 1990. These are generalized plans that can be applied to different situations that may threaten the well being of the community. They will identify key decision-makers and set out their areas of jurisdiction. Even if it has nothing specific to say about water, it will in many cases contain a crisis-communication strategy. Developing a water quality contingency plan without consulting existing emergency plans may therefore involve unnecessary effort and increase the potential for conflicts and confusion.

Consideration should also be given to inter-jurisdictional consultation. During development or revision of these plans, it is advisable to do so in consultation with the local utility and the MOE.

An effective plan will include the following elements:

Definitions of adverse Drinking Water results

This will be primarily based on the parameters of the ODWS. Ontario Regulation 459/00 defines indicators of adverse water quality and identifies corrective actions for each in Schedule 6, whose focus is on bacterial contaminants – E.Coli, Total Coliform and Heterotrophic Plate Counts (HPC) – that exceed MAC. In addition to these, a sample that indicates insufficient chlorine residual qualifies under this section. In each case, the local MOH is notified, and there is a built in assumption that he or she may require corrective actions that are different from those set out in this Schedule. It is because of this assumption that it is essential that response procedures are clear and appropriately prioritized.

The Association of Local Public Health Agencies recently made a series of recommendations as part of a response to Ontario Regulation 459/00 (Appendix 1). One of these was to ensure that the appropriate level of urgency is attached to a given adverse result. An elevated HPC is not necessarily going to require the same response as an elevated count of E.Coli. With this understanding, it was proposed (as is the practice in many health units) to divide adverse reports into two categories. Response to lower-risk incidents might require increased monitoring, resampling and notification, while the higher-risk incidents may require flushing of the system, increasing chlorination and issuing boil water advisories or orders. In order to determine which response is employed, explicit criteria for categorizing incoming reports must be defined.

Clear procedures to be followed

Specific details about what to do and by whom when such reports are received must be provided in the written protocol. In order to ensure that they are followed properly, individuals with responsibility for any actions should be identified, and those individuals should be familiar with their assigned responsibilities. In most cases, this is facilitated by the inclusion of flow charts, up-to-date contact lists, phone trees and a recording system that will document all steps taken. A periodic review of the protocol by the health department should occur as often as needed (e.g. after personnel changes) and not less than annually, and should involve all staff to whom it makes reference.

Descriptions of the steps to be taken must be comprehensive, from the receipt and evaluation of the report to the decision to declare the incident closed. Notifications, types of information to record, resampling sites and frequency, and who does what (including alternates) are essential components of a good written procedure. Additionally, the health department's protocol should append any procedural requirements that appear in other documents. The Regulation, the ODWS and up-to-date information on the Safe Water program distributed by the Public Health Branch are all items that should be part of the package.

Public Information

Contingency plans by definition are invoked when preventive safeguards have failed. The failure of the safeguards discussed above may constitute a danger to public health. If a contamination problem reaches the taps of the end-user, he or she must be warned quickly, especially considering that most pathogens do not alter the taste, smell or appearance of the water.

It is essential that this information be disseminated as quickly and as widely as possible in order to minimize the potential effects of water-borne health hazards. How this is done will depend on the community, but the goal will always be that every individual is made aware of the problem and of any measures he or she should be taking to minimize risks to their health. Print and broadcast media, handbills, and door-to-door visits are all useful tools for the delivery of this type of information.

After determining which of these, alone or in combination, will have the greatest coverage, it is essential to include a written, up-to-date communication strategy in the plan. It should include contact lists for local media, print services for handbills and any other external agencies with a role, as well as clear identification of persons responsible for all of the necessary tasks. It may also be useful to include a list of institutions that should be directly notified due to greater risks associated with decreased natural immunity or service of large numbers of people. Examples of this include hospitals, day cares, long term care facilities, prisons and food processors.

Having determined the methods of communication, it is also important to define the content of the messages. Issuing a boil water advisory for example should define what it is, how to do it properly, why it is necessary and effective, and how to obtain further information.

The responsibility for alerting the public to the existence of water quality problems is a shared one. This underscores the importance of clear procedures for public information. It should be coming from one source, the key messages should be consistent and those responsible for disseminating the information must be prepared to respond to public concerns. If the information is consistent and complete, the community is much more likely to accept it as good information. As long as the contingency plan is in effect, it is also very important that information continue to flow. The community must be kept informed of steps that are being taken to remedy the situation.

The decision to issue boil water advisories or orders rests with the medical officer of health, and there should be criteria spelled out for when this decision should be made and how it is to be disseminated. While consistent province-wide standards for the former would be useful, the process of informing the public will differ among the health units.

For example, in a situation where adverse water quality is suspected but not yet confirmed, a local health unit might deem it useful to communicate with public facilities such as hospitals, Long Term Care Facilities and large restaurants before informing the public in general. Information is the most important component of the contingency plan that is invoked at this point in the process. If the water coming from the consumer's tap is unfit for drinking, the first order of business is ensuring that the water is not consumed.

Conclusion

As drinking water is essential to the sustenance of life itself, the importance of ensuring its availability and safety cannot be overstated. The implementation of strategies for the exclusion of all forms of disease-causing agents from drinking water is arguably the most important safeguard of public health possible. This requires detailed examinations of all potential contaminants and the identification of means to prevent them from reaching the point of use. These examinations will be undertaken by different authorities depending on the point in the process, and should always be conducted with one eye on sustaining the resource and another on protecting the health of its users.

Careful consideration must be given to assessing the quality of the source, protecting it from contamination, and monitoring it for changes in the long term. Evaluating and regulating risks from surrounding land uses and the regular byproducts of human activity is also required. Once this is done, the nature of the distribution system can be examined, to ensure that its treatment, monitoring and operational procedures are appropriate for the source and for the community it serves. Finally, strategies must be in place to ensure that mechanisms are in place to ensure that any imminent threats to public health are quickly identified and appropriately dealt with.

Because these considerations involve so many agencies, it is essential that each have a general familiarity with the source-to-tap flow of drinking water. Ministries of Health, Environment, and Natural Resources, conservation authorities, local boards of health, municipalities, public utilities and laboratories are among many that have degrees of responsibility for quality assurance of drinking water. It is thus important that each has the expertise and the resources required to properly carry them out. It is also essential that each be aware of the basic functions of the other, so that all of the strategies that are implemented to protect water and the health of its consumers form a unified, effective and comprehensive quality system that will greatly reduce the incidence of water-borne disease.

The new water regulation, has taken important steps to address some of the shortfalls in the water delivery system by clarifying reporting duties, assigning responsibilities and giving the Ontario Drinking Water Objectives the weight of law through adoption by reference. It accounts for the shared responsibilities of the Health and Environment officials, it imposes the reporting requirements on private labs that were lost when water testing was removed from public labs, and tightens up testing and monitoring requirements. Proposed standards for agricultural operations and government initiatives for more stringent monitoring and protection of water sources are also encouraging signs that safeguards of water quality are increasing.

In the preceding analysis of the process of extracting water from its source and delivering it to the public, a complex web of interconnected processes has been illustrated. For all of the fragmentation of responsibility, division of labour and diversity of expertise involved, the unifying factor is the end goal – to ensure that the water coming out of the tap of the end user poses no threat to his or her health. Following the Walkerton tragedy, many analysts spoke of the recent complacency over the safety of drinking water. The fact is that with the implementation of and constant vigilance over appropriate controls, which are known and in many cases already in place, the end user should be permitted to take the safety of his or her water for granted. It is up to regulatory agencies, government ministries and technicians who are involved in the delivery of that water to give that permission.

Each of the agencies and individuals identified in this paper has a responsibility as links in a chain to ensure that theirs remains strong. This requires using resident expertise and resources to carry out the risk evaluations, monitoring functions, reporting duties and abatement strategies required of them to contribute to the achievement of that goal.

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APPENDIX 1

***RECOMMENDATIONS MADE BY THE alPHa WORK GROUP ON LARGE WATER SYSTEMS ONTARIO REGULATION 459/00,* DRINKING WATER PROTECTION, *MADE UNDER THE* ONTARIO WATER RESOURCES ACT.**

The following represents the response of the members of the Association of Local Public Health Agencies (alPHa) to the new *Drinking Water Protection Regulation (O. Reg. 459/00)* published in the Ontario Gazette on August 26, 2000, under the *Ontario Water Resources Act (R.S.O. 1990, c. O.40.).*

As the centrepiece of Operation Clean Water, the Ministry of the Environment's plan to ensure the safety of the province's drinking water, this new regulation prescribes strict standards for water treatment, monitoring, reporting, and corrective actions, and identifies persons having responsibility for each. The detailed nature of these standards is a strong indication of the Ministry of the Environment's commitment to its plan. The requirements will ensure increased vigilance by water works operators and owners, and that reporting of and response to water quality problems are timely and effective.

This regulation specifically prescribes responsibilities for the medical officer of health, the health unit's on-call staff and public health inspectors. Given that those positions are primarily defined and governed by statutes, guidelines and directives that originate from the Ministry of Health, alPHa feels that it is essential to ensure that the new regulation's clauses and public health staff roles as defined by them are clear.

The impact of O. Reg. 459/00 on Health Departments:

On the surface, the Health Department's role defined in the regulation appears to be advisory in nature and has been reduced to a reactive response that commences **only** upon notification of a potential health hazard. It is important to note that public health has a mandated interest in ensuring the provision of safe water and should be considered an essential and active partner in helping the Ministry of the Environment achieve its goals under Operation Clean Water.

What is the statutory obligation of the Health Department?

The Health Protection and Promotion Act (R.S.O. 1990, c.H.7.) states in section 2 that "*The purpose of this Act is to provide for the organization and delivery of public health programs and services, the prevention of the spread of disease and the promotion and protection of the health of the people of Ontario.*

Section 5 of the H.P.P.A. states that *"Every board of health shall superintend, provide or ensure the provision of health programs and services in the following areas: 1. Community sanitation,* *to ensure the maintenance of sanitary conditions and the prevention or elimination of health hazards".*

Section 9 of the H.P.P.A. states that " *The board of health may provide any other health program or service in any area in the health unit served by the board of health if, (a) the board of health is of the opinion that the health program or service is necessary or desirable, having regard to the needs of persons in the area; and (b) the councils of the municipalities in the area approve of the provision of the health program or service."*

Section 10.(1) of the H.P.P.A. states that *" Every medical officer of health shall inspect or cause the inspection of the health unit served by him or her for the purpose of preventing, eliminating and decreasing the effects of health hazards in the health unit".*

The Mandatory Programs and Services Guidelines, published by the Ministry of Health, includes a Safe Water Program that requires boards of health *"to ensure that community drinking water systems meet the health-related chemical, physical, microbiological and radionuclide objectives as published in the Ontario Drinking Water Objectives* (replaced by Ontario Drinking Water Standards Aug. 26, 2000) *and the Guidelines for Canadian Drinking Water Quality (sixth edition)"*. This would suggest an active role by health unit staff in monitoring water quality and offering expertise on solving water quality problems.

In light of the Walkerton tragedy, there is growing public and political perception and expectation for Health Departments to have shared responsibility with the water works owner and MOE in ensuring the delivery of a safe water supply. We accept this responsibility and make the following recommendations:

1. **Section 5 Clarification**. Clause (1) requires disinfection, where clause (2) allows for "other treatment capable, in the Director's opinion, of producing water of equal or better quality." Concerns raised here were: not knowing who the Director is; the fact that Medical Officer of Health approval is not required for variances under this section (as it is in section 6, where water is drawn from a subterranean source); and discomfort over what kind of treatment alternatives might be permitted.

   Recommendation: define "Director" in the regulation, require Medical Officer of Health input on all approvals for variance under the present regulation and require minimal levels of chlorination in all cases.

2. **Section 8 Clarification.** While this section allows for notification of the medical officer of health via other personnel under subsection (6)(a), concern was expressed that this clause is not obvious enough.
   Concerns were also raised surrounding the off-hours notification of the Ministry via the Spills Action Centre. Because of the Centre's location, concerns were raised about the timeliness of response, especially to reports originating from distant areas.

Recommendations: ensure that those responsible for issuing notice of water quality problems under section 8 are aware that alerting persons identified in clause (6)(a) constitutes proper notification for the purposes of this section. Ensure that procedures are in place to ensure that the response from the Spills Action Centre is timely and effective, regardless of the geographical origin of the notice, e.g. a built-in redundancy to ensure that the Centre contacts its local MOH or person identified under sub. (6)(a)

3. **Section 10 Clarification.** In clause (3), "provincial officer" is not defined. Does this mean provincial offences officer under the Provincial Offences Act or officers designated under the authority of other acts?

4. **Section 11, Public Information, Addition**, Given that the first point of inquiry about health hazards in a given community is often its local health unit, the intent of this section would be better served if the information itemized within were directly accessible through the health unit.

   Recommendation: That the local Health Unit be added to the locations under subsection (2) at which the owner of the treatment or distribution system is required to make information available for the purposes of this section.

5. **Section 12, Quarterly Reports**: For the same reasons set out above regarding section 11, copies of the reports prescribed by this section should be furnished to the Health Unit independently of a formal request.

   Recommendation: That the owner of the water treatment or distribution system be required to submit reports required under this section to the local Medical Officer of Health, Water Quality or Program Manager of the Health Unit.

6. **Schedule 6**, Item 4, regarding HPCand item 5 regarding total coliforms leave out specific corrective actions and impose the decision on these on the medical officer of health. Regarding item 6 (*aeromonas*, *pseudomonas*, *staphylococcus spp.* etc.), no parameters are set out in Schedule 2 for testing or in schedule 6 for corrective action.

General Recommendations

1. Clearer references should be made to the requirements set out in the Ontario Drinking Water Standards. The document is referenced in the present regulation, but clarity regarding its application is lacking. The concern is that required standards for water quality parameters that are not specifically mentioned in the attached schedules, such as viruses and protozoa, may be overlooked.

2. An allowance for the prioritization of reporting of and response to adverse water quality notices should be made. A potential lack of understanding of what the numbers mean at the Spills Action Centre may led to unnecessary urgency being attached to certain incidents. Recommendation is to categorize urgency of adverse water reports into two levels with corresponding response times.

3. A clearer role in water quality under this regulation for the Health Departments should include routine reviews of reports, studies and surveys by water works owners as well as routine microbiological sampling and Free Available Chlorine (FAC) measurements throughout the distribution system of the water works.

4. Guidelines should be published for Health Departments for responding to adverse water sample result notifications.

5. The Safe Water Standards should be reviewed and revised through a Technical Review Committee on an urgent basis.

APPENDIX 2

ASPHIO

The Association of Supervisors of Public Health Inspectors of Ontario
(Incorporated 1982)

September 15th, 2000

Ontario Ministry of Agriculture, Food and Rural Affairs
Resources Management Branch
3rd Floor, 1 Stone Road West
Guelph, Ontario, N1G 4Y2

Re: Proposed Standards for Agricultural Operations in Ontario

Thank you for providing the opportunity to comment on the recently issued *Proposed Standards for Agricultural Operations in Ontario.*

In July, I received the proposed standards that had been developed in part from the collective input from many sources during the *Consultation on Intensive Agricultural Operations in Rural Ontario.*

The proposed standards still require clarification on some areas, such as:

- enforcement issues (municipal, provincial or combination).
- non-compliance penalties in the proposed legislation.
- Standards
- Suitability of livestock units as the basis for defining various categories of livestock farms.

While the documents detailed a variety of options for each of the above components, our recommendations are for the following:

- Strong and consistently applied provincial enforcement and monitoring.
- High minimum and maximum fines for non-compliance. Provisions for responsibility for clean up costs where environmental impairments extends beyond the farm gate should also be considered.

- Standards for buildings, waste collection, storage and disposal/application of manure/agricultural wastes to be very stringent.
- Training, certification and documentation standards that extend to those in the business of applying and hauling wastes on agricultural lands.
- Detailed hydro-geological verification monitoring of nutrient application sites on a very regular schedule to ensure that groundwater and surface water resources are not being impaired in the vicinity of the agricultural operation.

While these comments provide some direction toward some clarification, the real issue, as seen in the public health community, is the protection of the public from negative health impact (i.e. morbidity and mortality) from exposure to contaminated groundwater or surface water.

A significant number of Ontario residents rely on groundwater for drinking water. Diverse interests for groundwater resources have impacts on quality and quantity. It is essential that this type of proposed agricultural standards and legislation not be established in isolation.

As you know, several provincial Ministries share responsibility for groundwater management – Environment, Agriculture, Food and Rural Affairs, Municipal Affairs and Housing and Natural Resources. Any agricultural legislation that has an impact on the protection of groundwater must correspond, complement and contribute towards the development of a comprehensive groundwater management and protection strategy.

The recent special report from the Environmental Commissioner of Ontario suggested that a groundwater strategy could include the following elements:

- A groundwater resources inventory and data management system.
- Identification and protection of sensitive aquifers and groundwater recharge areas.
- A strong regulatory program aimed at preventing contamination.
- A means of coordination decision-making between all Ministries and agencies that have jurisdiction over groundwater, with Environment playing the lead.
- An inventory of current and past uses of groundwater and sources of groundwater contamination and an evaluation of their potential effect on health and ecosystems, including cumulative impacts.

It would be prudent at this time, that the key Ministries noted above, along with the Ministry of Health and Long-Term Care, immediately begin developing a coordinated legislative approach to groundwater protection and stewardship that incorporates the above elements and positions the proposed agricultural standards being considered in this process, within the context of groundwater protection.

While we've provided some comments on the areas of clarification identified through this consultation process, we have expressed the need for this to be put into proper context. These comments are meant to help set a course of action that will coordinate groundwater protection where there is a strong regulatory framework for provincial agents to lead the approvals process, monitoring process, enforcement process and research process.

Until this can be established, it would be prudent to enact an interim moratorium on new or enlarged intensive agricultural operations, unless arrangements can be made for primary and secondary treatment of agricultural wastes at municipal sewage treatment facilities, with no additional application of agricultural wastes beyond current levels in approved nutrient management plans.

We look forward to the final draft of this legislation and strongly recommend that it be strategically positioned within a coordinated multi-ministry effort to establish and implement a groundwater protection and stewardship strategy.

It's time to rethink the "business as usual" approach to applying excessive amounts of a range of agricultural and municipal wastes onto concentrated land areas, to the detriment of groundwater, putting drinking water sources and possibly the health of millions of rural Ontarians into peril.

Yours sincerely,

James Reffle, BA, MPA, CPHI(C)
ASPHIO President
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cc: Association of Local Public Health Agencies
Environmental Commissioner of Ontario
Ontario Public Health Association
Ontario Ministry of Health & Long-Term Care

JR/jr

APPENDIX 3

ASPHIO Recommendations Concerning Ontario Regulation 903 Respecting Wells.

ASPHIO The Association of Supervisors of Public Health Inspectors of Ontario (Incorporated 1982)

ASPHIO EXECUTIVE MAY 2000 TO MAY 2002

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December 29, 2000

Ontario Ministry of Health and Long-Term Care
Public Health Branch
C/o Mr. Fred Ruf, Senior Policy Analyst
8th Floor, 5700 Yonge Street
Toronto, Ontario M2M 4K5

Dear Mr. Ruf,

Re: **Ontario Regulation 903 Respecting Wells**

In response to your December 19th , 2000 fax memorandum to all Public Health Units in Ontario, regarding the opportunity to provide comments on the above noted regulation, below please find our preliminary comments and suggestions that you requested.

It is our understanding that comments forwarded to the Public Health Branch will be provided to the Land Use Policy Branch of the Ministry of the Environment, whose staff are currently reviewing this legislation.

We have also provided these comments to the Safe Water Working Group - Private Water Systems, that has been established under alPHa. This working group is in the process of reviewing the issue of Public Health's role with respect to private water systems. Members include Medical Officers of Health and Directors/Managers of Environmental Health, representing ASPHIO, from various Health Units in Ontario.

It is ASPHIO's preliminary view that Regulation 903 needs to be strengthened as noted below and that a priority should be to add adequate human resources to properly monitor and enforce this regulation. More thorough enforcement is needed to confirm that qualifications of well technicians are current and applicable to the work completed. Once additional staffing is in place all new wells need to be inspected. Also abandoned wells require inspection to confirm compliance with the regulation. This is not occurring often enough, if at all.

- **Sect. 6(3) 1.** Some kind of monitoring system should be in place to ensure that where an apprenticeship is offered to obtain the required qualifications, a minimum training content is provided.
- **Sect. 8. 8. (1)** Examinations developed should be consistent in content areas and types of questions for all areas of the province.
- **Sect. 11 (4) (a) and 15. 15 (1)** Reference is made to providing a water sample to the owner of the well (for viewing) and for chlorination to occur. A declaration from the installer or plumber should be included in the well record documentation that chlorination did actually occur and the methodology that was used. A bacteriological sample should also be provided (minimum 3 consecutive) as an indication of the potability of the supply. Analysis for Nitrate and Fluoride should also be included in the suite of tests once the supply has been declared suitable for use. Alternatively, as a bare minimum the owner should be advised (on the well certificate or separate info) to sample the new supply within 30 days to establish a base line potability status.
- **Sect. 11 (5), Sect. 12. and the final well record form.** The diagram provided on the well record should be detailed enough to indicate where on-sewage systems and other sources of pollution are located in relation to the well. Confirmation is needed that the proper distances have been provided, especially in situations where the well is drilled after the sewage system has been installed. Distance to neighbouring sewage systems needs to be included.
- **Sect. 12. (2), 12(7)** Manure storage needs to be mentioned specifically as part of the definition of “source of pollution”.
- **Sect. 14 (6) and 14 (7**) The opportunity to drill a well within a shallow well and this section should be deleted and outlawed. There have been numerous examples of drilled well contamination where this situation has been allowed.
- **Sect. 17** Where a well pit exists, or is allowed for a new well installation, confirmation is needed that proper drainage is provided in situations where flooding of the pit may occur.
- **Sect. 20** As part of contamination control, backflow prevention devices should be required where a line from the well serves more than one user type. I.e. barn and house or shed. This is especially important where the well is new but serving older buildings that may not meet the OBC Part 7 (plumbing code).
- **Sect. 20(3)** Add a section, which requires certification or documentation that the owner understands their responsibility in protecting the well from contamination that is referred to in Sect. 20 (3)
- **Sect. 21** Municipalities should be required to document and have a database of all abandoned wells with a monitoring requirement to ensure that contamination is prevented through proper abandonment or protection provided where the usage is infrequent. Reference should also be made to the OBC Part 8 (sewage systems) that all abandoned wells within the required distances are identified and properly filled in.
- **Sect. 21 (5)** Specific reference is needed to require inspection or confirmation that well has been properly abandoned. Similar documentation is needed that confirms that the well is ready for use as per the regulation.

- **Forms.** An emergency 911-locator number should be included in all forms with address or lot and concession information requirements where applicable.

These are our preliminary comments on the Regulation, given the very short response time. We trust that there will be additional opportunities for us to make further comments on revisions proposed by the Ministry of the Environment.

We also expect that this Regulation will be part of an overall groundwater protection strategy that ASPHIO called for in our September 15th comments to OMAFRA's Proposed Standards of Agricultural Operations. The need for a coordinated, comprehensive approach to groundwater protection was also recommended by the Environmental Commissioner of Ontario, Gord Miller.

The Safe Water Working Group's comments should also be taken into account when this Regulation is amended and when the Public Health Branch revitalizes the Safe Water Mandatory Program.

Thank you for allowing us the opportunity to make these preliminary comments on this important legislative review. If you have any questions of clarification, please contact Klaus Seeger, who reviewed the Regulation on behalf of ASPHIO, at the Oxford County Board of Health.

Yours truly,

James Reffle, BA, MPA, CPHI(C)
President, ASPHIO

Cc: The Honourable David Newman - Minister of the Environment
Gord Miller - Environmental Commissioner of Ontario
Andy Papadopoulos - Executive Director alPHa
Suzanne Shaw - President of CIPHI (Ontario Branch)
Bill Hunter - MOHLTC - Public Health Branch
Helen Doyle - Safe Water Working Group - Private Water Systems